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#236 JANUARY 2025

Sky at Night

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SPACE IN 2025

The biggest launches and mission milestones in the year ahead

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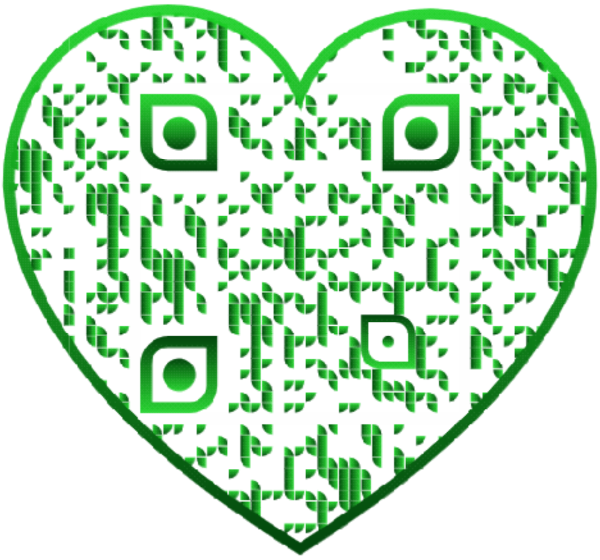

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Welcome

The countdown begins on an exciting year of space discovery

There's much to look forward to in the arena of space exploration in 2025, and to kick off our first issue of the year, on **page 28** Jamie Carter takes a look at the biggest missions that are set to launch in the next 12 months. These include the latest test launch of Starship, SpaceX's rapidly evolving spacecraft, atop its Super Heavy booster. Together they make the most massive and powerful rocket ever to fly – which makes the fact that both are designed to be reusable even more astounding.

Among the other pivotal missions taking off is Artemis II, the first crewed mission to enter lunar orbit in more than five decades. That's a long time to wait, especially when you consider that NASA developed a roadmap back in the 1960s for missions to follow on from the Apollo Moon landings, including plans for a permanent crewed presence on the Moon and beyond. On **page 66**, Ben Evans investigates the reasons behind this pause in deep-space exploration, putting today's commercial spaceflights into context.

As well as keeping an eye on launch manifests, we've also been looking ahead to notable stargazing moments coming up in 2025. Mars will be resplendent right from the off, coming to opposition in mid-January, when it will be at its highest and brightest until 2027. There are also four eclipses to look forward to this year, two lunar and two solar. Find more observing highlights on **page 32** and get details of this month's best observing in the Sky Guide on **page 43**.

Enjoy the issue and the New Year!

Chris Bramley, Editor

PS Our next issue goes on sale on Tuesday 21 January 2025.

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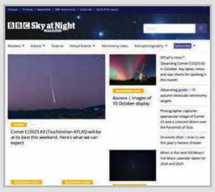
Sky at Night – lots of ways to enjoy the night sky...

Television

Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



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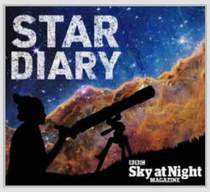

Podcasts

Discover the best things to see in the night sky every week by listening to our Star Diary podcast

Tablet/phone

Get each month's issue on your Apple or Android device, now with bonus image galleries

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COVER IMAGE: SPACE X. THIS PAGE:SNS, ALAN DYER/STOCKTREK IMAGES/GETTY, SPACE X, PETE LAWRENCE X 2, MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, @THESHED_PHOTOSTUDIO, NASA'S SCIENTIFIC VISUALIZATION STUDIO, ELEN11/ISTOCK/GETTY, NASA, CHRISTOPH BURGSTEDT/SCIENCE PHOTO LIBRARY, CRAIG DIXON

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**

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This month's contributors

Jamie Carter

Astronomy journalist

"It's going to be an exciting year, from Mars and Venus at their brightest to China's Tianwen-2 mission to a near-Earth asteroid and NASA's Artemis 2, the first crewed mission to the Moon for 53 years." **Read more on page 28**

Charlotte Daniels

Astrophotographer

"Mastering planetary imaging doesn't mean missing out on deep-sky targets. There are plenty of ways to adapt our Solar System setups to capture those fainter objects!" **Jump in the deep end on page 34**

Ben Evans

Spaceflight author

"Back in the '60s, the Space Race put a man on the Moon within a decade. Half a century on, getting back there is taking a lot longer. But what will our next steps on the lunar surface actually look like?" **Find out on page 66**

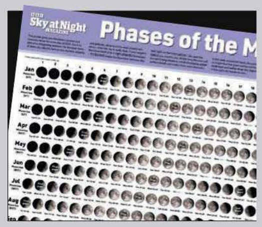
FREE BONUS CONTENT

Find it at **www.skyatnightmagazine.com/bonus-content**

JANUARY HIGHLIGHTS

How space rocks brought life to Earth

Rayssa Martins discusses her research on the meteorites that delivered the vital ingredients for life to flourish.



Download a free 2025 Moon phases poster

Whether you love a full Moon or bemoan its glare, our 2025 digital poster reveals the lunar phases for the year ahead.

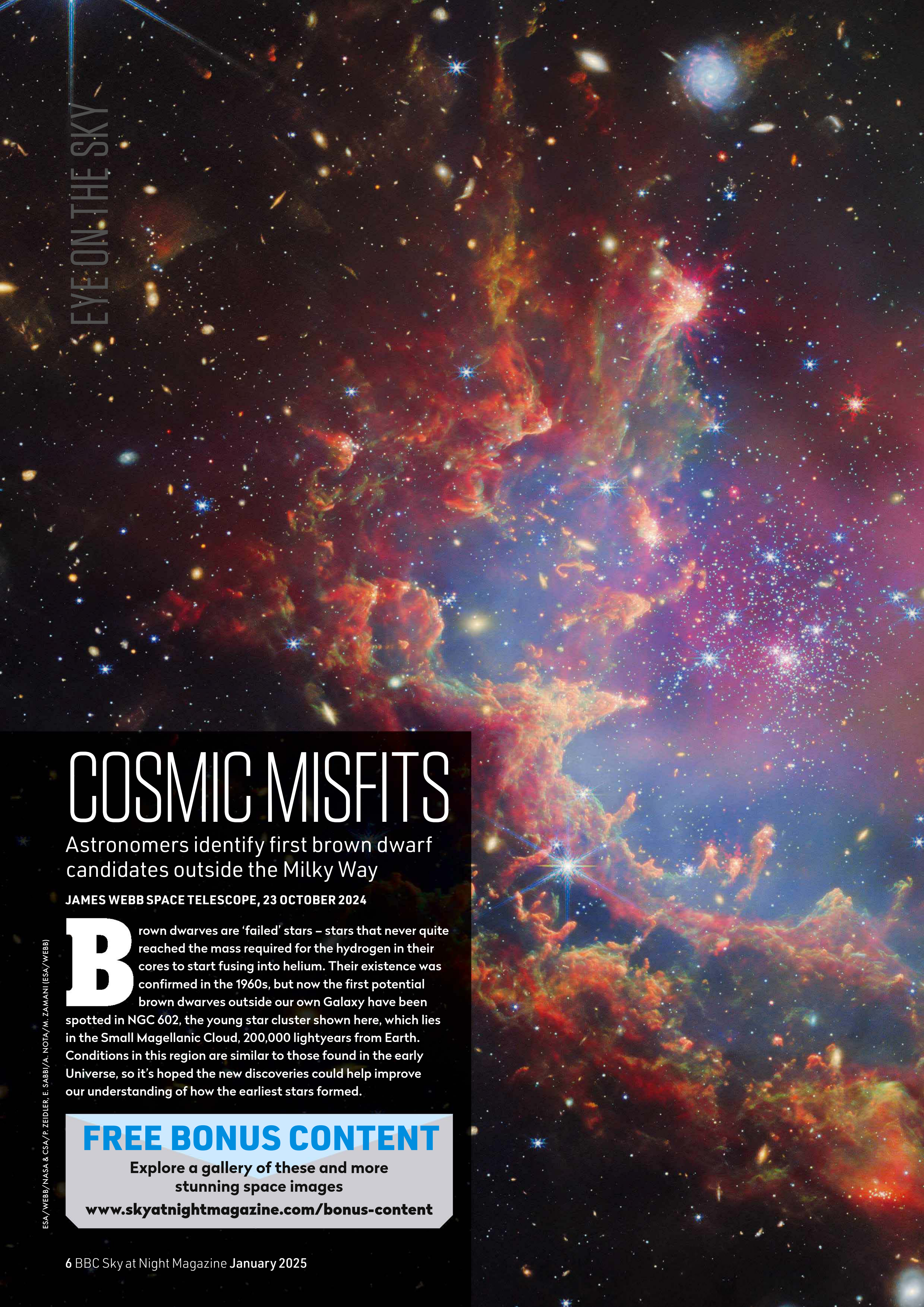
Best cosmic images from our readers

Our extended gallery showcases some of the best astro photos captured by you over the past few months.

The Virtual Planetarium

Beta Eridani
Beta Orionis
IC 2118

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.



COSMIC MISFITS

Astronomers identify first brown dwarf candidates outside the Milky Way

JAMES WEBB SPACE TELESCOPE, 23 OCTOBER 2024

Brown dwarves are 'failed' stars – stars that never quite reached the mass required for the hydrogen in their cores to start fusing into helium. Their existence was confirmed in the 1960s, but now the first potential brown dwarves outside our own Galaxy have been spotted in NGC 602, the young star cluster shown here, which lies in the Small Magellanic Cloud, 200,000 lightyears from Earth. Conditions in this region are similar to those found in the early Universe, so it's hoped the new discoveries could help improve our understanding of how the earliest stars formed.

ESA/WEBB/NASA & CSA/P. ZEIDLER, E. SABBI/A. NOTA/M. ZAMANI (ESA/WEBB)

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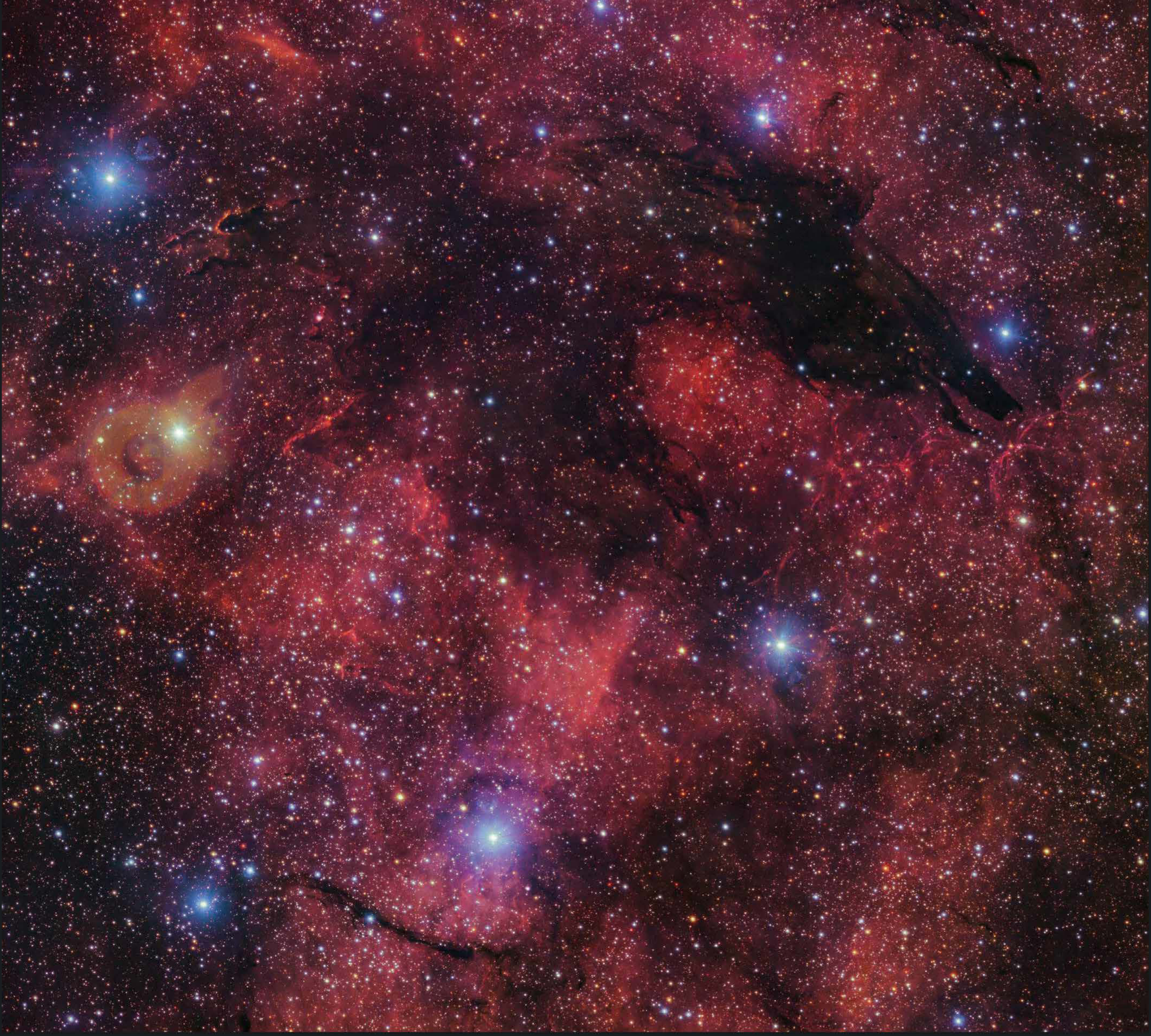
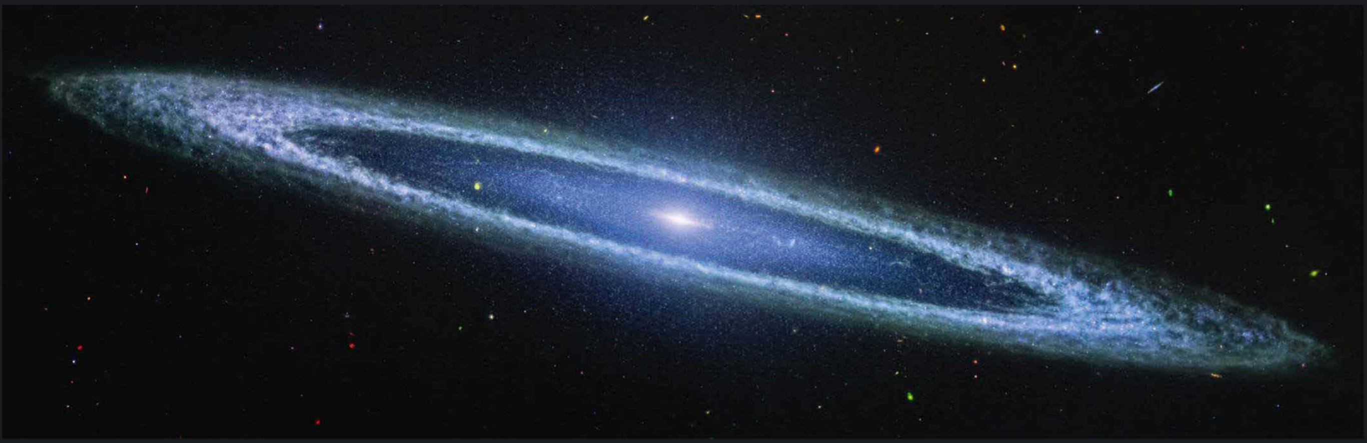


△ Lone wolf

VLT SURVEY TELESCOPE (VST), 31 OCTOBER 2024

Definitely a lesser-spotted cosmic canine, this one! The Dark Wolf Nebula, also known as SL-17, is a dark nebula in the southern constellation of Scorpius. This 283-million-pixel image was captured as part of the VPHAS+ (VST Photometric Hα Survey of the Southern Galactic Plane and Bulge), which has studied over 500 million Milky Way objects.

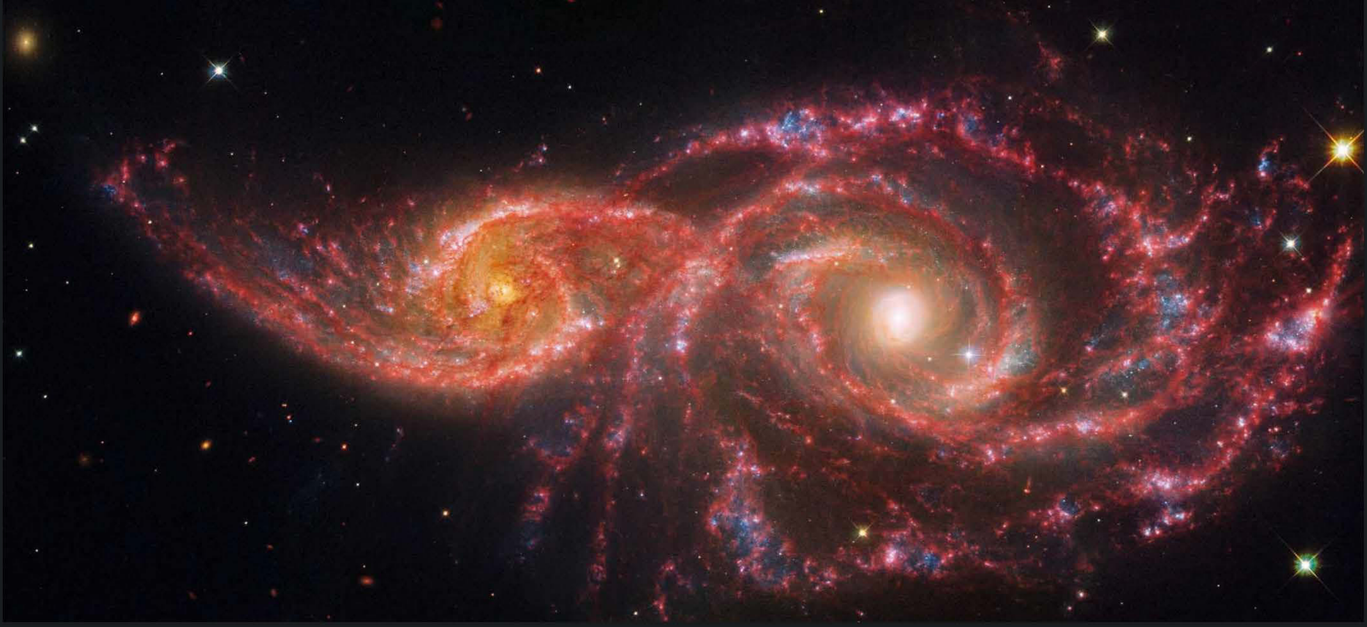


△ Kind of blue

JAMES WEBB SPACE TELESCOPE, 25 NOVEMBER 2024

Seen here is the Sombrero Galaxy, a spiral galaxy lying 30 million lightyears from Earth in the constellation of Virgo, as captured by the JWST's Mid-Infrared Instrument (MIRI). Unlike previous images of this galaxy, this infrared version reveals a smooth inner disc and, for the first time, the intricate clumps of gas and dust in the Sombrero's outer ring.

ESO/VPHAS+ TEAM, NASA/ESA/CSA/STSCI, NASA/ESA/CSA/STSCI, INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA. IMAGE PROCESSING: J. MILLER & M. RODRIGUEZ (INTERNATIONAL GEMINI OBSERVATORY/NSF NOIRLAB) T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB) M. ZAMANI (NSF NOIRLAB). ACKNOWLEDGEMENTS: PI: JISU KANG (SEOUL NATIONAL UNIVERSITY)



△ Just getting started

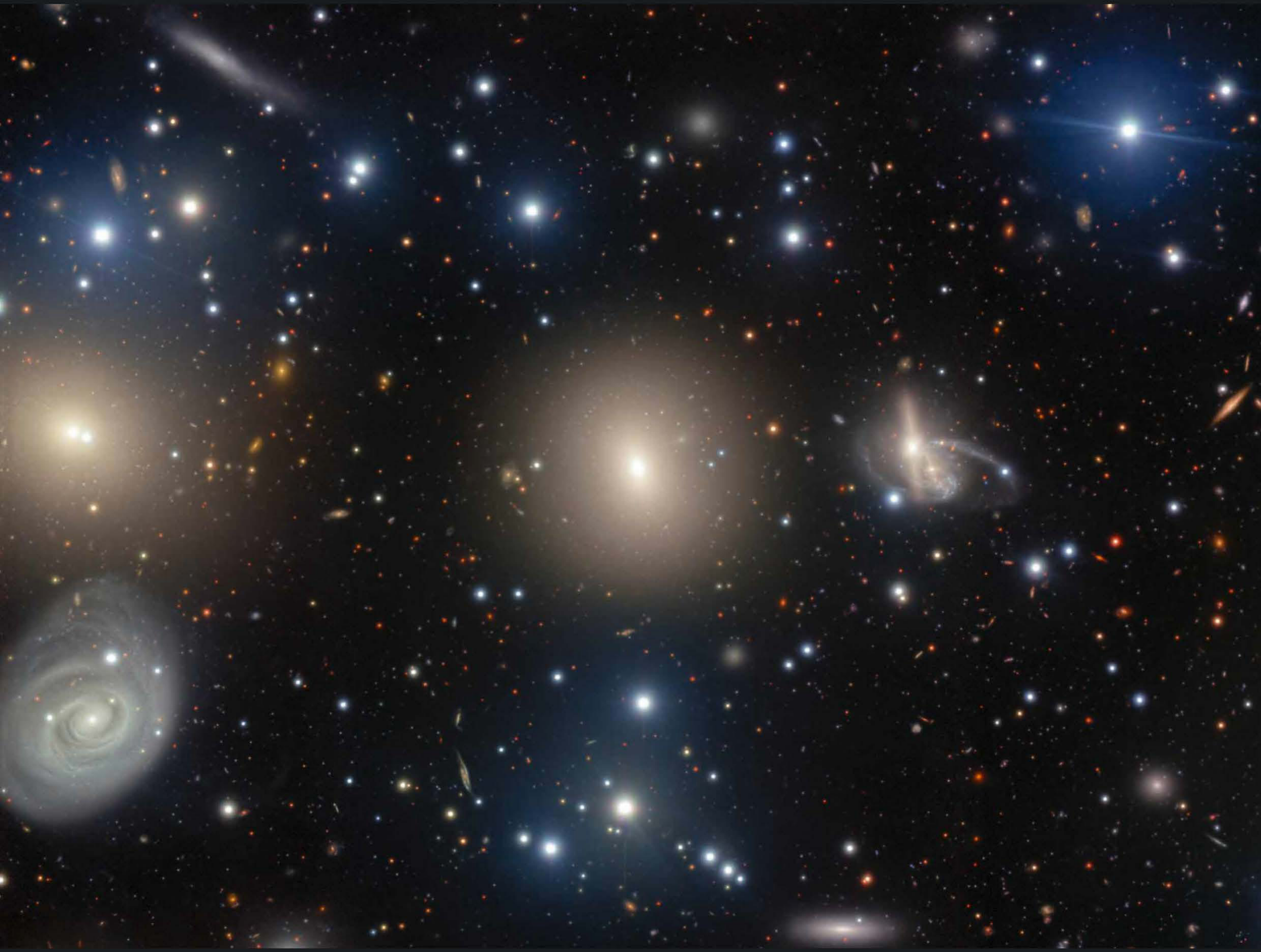
HUBBLE SPACE TELESCOPE/JAMES WEBB SPACE TELESCOPE, 31 OCTOBER 2024

This pair of spiral galaxies, IC 2163 (left) and NGC 2207 (right), sidled close to one another several million years ago, but have yet to collide – though it's believed the duo's combined gravitational fields may be causing their spiral arms to stretch.

▽ Among friends

GEMINI NORTH TELESCOPE, 21 OCTOBER 2024

The hazy circular glow at the centre of this image is NGC 1270, an elliptical galaxy that lies at the heart of the Perseus Cluster. But NGC 1270 is just one of countless thousands of galaxies that comprise the enormous cluster – over a dozen of which are visible in this picture alone.



This was Sylvia's promise to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And surviving a stroke is just the start of a long and gruelling recovery journey. If you or someone you love has been affected by stroke – you'll know just what that means.

You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries, and stroke survivors and their families have the support to find the strength and determination they need to find their way back to life.

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Find out how by calling 020 7566 1505
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The Stroke Association is registered as a charity in England and Wales (No 211015) and in Scotland (SC037789). Also registered in the Isle of Man (No. 945) and Jersey (NPO 369), and operating as a charity in Northern Ireland.

Chance of finding intelligent aliens gets slimmer

New equation suggests our Universe had low odds of forming life

ILLUSTRATION

The formula suggests tallying up dark matter could be what tells us if life is likely in our Universe and any others

For 60 years, astronomers have used the Drake equation to investigate the likelihood of intelligent life evolving elsewhere in the Universe. Now, researchers have devised a novel method to examine the question by looking at one of the fundamental properties of our Universe: the fraction of dark energy it contains.

Created by Dr Frank Drake in the 1960s, the Drake equation attempts to calculate the number of intelligent, technologically advanced species in the observable Universe. It uses various factors to work out the number of habitable planets in the Universe and the likelihood of those planets creating advanced civilisations; but as many of these quantities are currently unmeasurable, it's more a discussion point than a workable scientific tool.

The new study instead looked at how likely it was for stars and planets – considered vital precursors for life – to form in a universe with a certain amount of dark energy, examining how star formation changed if the fraction of dark energy changed. Dark energy is the mysterious substance that is theorised to be accelerating the Universe's expansion, and is thought to make up ~70 per cent of our Universe.

"Understanding dark energy and the impact on our Universe is one of the biggest challenges in cosmology and fundamental physics," says Daniele Sorini from Durham University, who led the study. "The parameters that govern our Universe, including the density of dark energy, could explain our own existence."

Too much or too little dark energy would change the Universe's ability to form structure, and so alter the number of stars being produced. The study found that in the best-case scenario, dark energy allowed 27 per cent of gas to form stars.

Our Universe converts around 23 per cent, meaning we don't live in a universe that has the highest odds of forming intelligent life, suggesting there could be some other special ingredients that allowed life to flourish at least once.

For a look at recent research into how life might form without a planet, turn to page 98.

www.ras.ac.uk

INGANIELSEN/ISTOCK/GETTY

Comment

by Chris Lintott

We'd like to be able to explain why our Universe has the recipe it does, why it has this combination of matter and dark energy stirred just right to create the cosmos we live in. It's tempting to reach for anthropic arguments – the idea that the Universe is the way it is because otherwise we wouldn't be here to see it.

This explains why we don't see a value of dark energy that is, for example, a million times larger than we do. Such a Universe would expand far too rapidly for stars or planets to form. But what this work shows is that we could happily exist in a universe with a wide range of values for dark energy – and so we still need a proper explanation for what we observe.

Chris Lintott co-presents *The Sky at Night*

▲ **The Chinese lander scooped up almost 2kg of lunar material and returned it to Earth for analysis last June**

CNSA/CLEP, NASA/JPL/USGS, NOIRLAB/NSF/AURA/J. DA SILVA/M. ZAMANI

The Moon's far side was volcanically active

Moonrocks from China's Chang'e 6 mission are revealing the Moon's hidden side

The mysterious far side of the Moon has given up one of its biggest secrets, as the latest analysis of samples brought back by China's Chang'e 6 mission has confirmed that the region definitely had a volcanic past.

The Chang'e 6 mission landed on the Moon's far side on 1 June 2024, swiftly collected 1.9kg (4.2lb) of lunar material and returned to Earth with it. Although planetary geologists have a wealth of moonrocks from the near side returned by the Apollo, Luna and previous Chang'e 5 mission, this was the first example from the far side.

Researchers hope the sample will help solve the long-standing mystery of why the two sides of our Moon look so different. While the familiar near side is covered with large, dark lunar seas (called mare) that were created by floods of lava, the far side has only a handful of much smaller ones. Instead, it is pockmarked by impact craters.

Impact craters build up over the lifetime of a planetary body, but can also be erased by volcanic activity, so geologists can examine their size and number to estimate when the surface last saw fresh lava. Using observations from orbital spacecraft such as NASA's Lunar Reconnaissance Orbiter, scientists were able to determine that the lunar far side has indeed experienced past volcanism – and on a similar timescale to that identified on the near side.

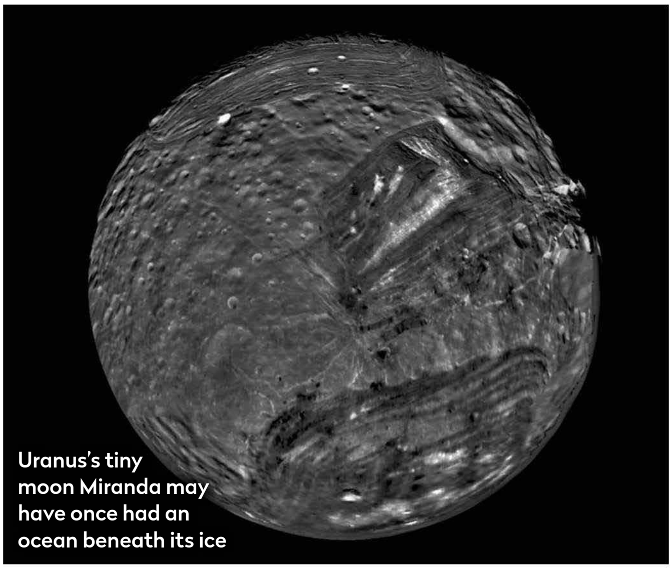
The only way to check for certain, however, is by examining a sample from the far side itself. When Chang'e 6's lunar samples arrived on Earth they were found to contain basalt, a volcanic mineral the lunar seas are made from. Analysing these grains found most of them were created 2.8 billion years ago (though one appears to be 4.2 billion years old). The Apollo and Luna samples, meanwhile, show that volcanic activity around the Moon's near-side equator was only active up to around 3.1 billion years ago.

Even more surprisingly, the Chang'e 6 samples have much lower levels of radioactive elements compared to the near-side samples. On Earth, the decay of these elements helps to keep the core warm and our planet's volcanism going. How the far side kept volcanic activity going without these elements is a mystery. It seems the far side still has some secrets to reveal.

www.cnsa.gov.cn/english

Miranda had a liquid water ocean

The finding challenges Voyager 2's data that suggested the Uranus moon was inert



Uranus's tiny moon Miranda may have once had an ocean beneath its ice

Miranda, one of 28 icy moons around Uranus, may have had a subsurface ocean, challenging our previous ideas. The find came just as NASA revealed that data from Voyager 2, our only close-up view of distant Uranus, may not have been interpreted correctly.

Voyager 2 flew by Uranus in 1986, imaging several of its moons. Its photos of Miranda showed a patchwork of grooved terrain and craters. A new study examined what geological processes could produce this appearance. It found the most likely scenario is that 100–500 million years ago, Miranda had a 100km-deep (62-mile) ocean beneath its ice shell. Miranda has a radius of just 235km (146 miles), meaning this ocean would take up most of the interior. Even now, the moon could still have the remnant of a thin ocean layer.

"To find evidence of an ocean inside a small object like Miranda is incredibly surprising," says Tom Nordheim from Johns Hopkins Applied Physics Laboratory, who took part in the study. "There may be several ocean worlds around one of the most distant planets in our Solar System, which is both exciting and bizarre."

At the same time, NASA has revealed that it might be time to rethink some of Voyager 2's measurements of Uranus. During the craft's fly-by, it found the magnetosphere – the magnetic bubble around the planet – curiously devoid of water ions. This seemed to suggest the moons were all frozen solid and therefore not releasing any water. However, a recent report revealed that Voyager 2 passed Uranus during an extreme space weather event that would have squashed the magnetosphere, reducing the number of ions the spacecraft saw.

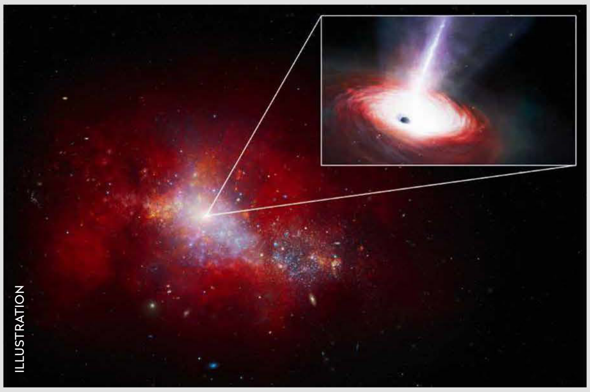
"If Voyager 2 had arrived just a few days earlier, it would have observed a completely different magnetosphere at Uranus," says Jamie Jasinski from NASA's Jet Propulsion Laboratory, who led the report. **www.nasa.gov**

Fast-feeding black hole breaks theory

The matter-guzzling frenzy appears to be a single, extreme bout of accretion

The fastest-feeding black hole in the Universe is apparently gorging on matter 40 times faster than what was thought theoretically possible, according to a recent set of observations.

The black hole, named LID-568, dates from when the Universe was just 1.5 billion years old and could potentially explain the mystery of why there appear to be so many black holes in the early Universe that were able to quickly grow to be behemoths.



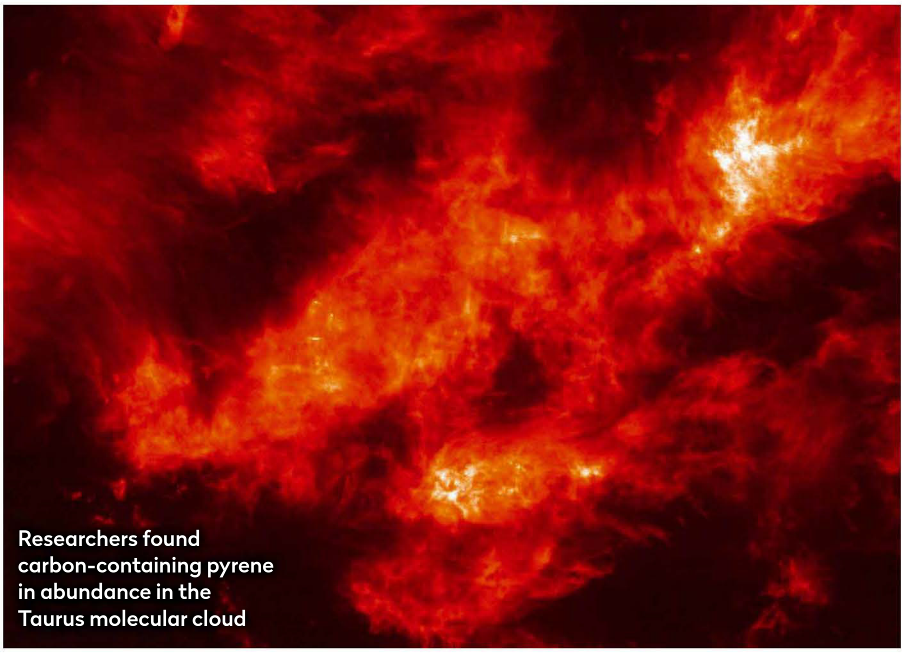
▲ An artist's impression of the red, early-Universe dwarf galaxy that hosts the ravenous record-breaking black hole

LID-568 is remarkably bright at X-ray wavelengths, but its infrared counterpart was so faint it could only be detected by the James Webb Space Telescope (JWST). JWST's observations revealed that the black hole was surrounded by powerful outflows of material. Theory states that there is a limit to how fast a black hole can feast on matter, set by something called the Eddington limit, but LID-568 appears to be pulling in matter at an incredible rate, 40 times greater than that theoretical limit. One suggestion is that the powerful outflows may have occurred in a single episode of rapid accretion and that they are acting as a release valve, helping the system to remain stable.

"This black hole is having a feast," says Julia Scharwächter from International Gemini Observatory/NSF NOIRLab, who took part in the study. "This extreme case shows that a fast-feeding mechanism above the Eddington limit is one of the possible explanations for why we see these very heavy black holes so early in the Universe." **www.noirlab.edu**

Source of Earth's carbon found

Study says life-giving element was in the cloud that birthed the Solar System



Researchers found carbon-containing pyrene in abundance in the Taurus molecular cloud

Carbon is one of the most important elements for the formation of life on Earth. Now a new study may have finally discovered how the element got to our planet, after finding a reservoir of carbon-containing molecules in an interstellar cloud similar to the one in which the Solar System was born.

The cloud contains pyrene, a type of chemical known as polycyclic aromatic hydrocarbons (PAH) which contain rings of carbon atoms fused together. PAHs make up 10–25 per cent of all carbon that exists in space and have long been touted as the potential source of carbon on Earth.

Pyrene has been found in many comets, asteroids and meteorites, most recently in 2023 in samples of asteroid Ryugu collected by the Hayabusa2 mission.

As these space rocks are the remnants of our Solar System's formation, these findings suggest that pyrene was delivered after the planets had formed. To see if it might have been present before they were created as well, a team of researchers looked at the Taurus molecular cloud (TMC-1), an interstellar cloud of gas and dust in the constellations Taurus and Auriga, which is in the process of forming stars and planetary systems of its own. They discovered it contained a large amount of pyrene.

"What we're looking at is the start and the end, and they're showing the same thing," says Brett McGuire from MIT, who took part in the study. "That's pretty strong evidence that this material from the early molecular cloud finds its way into the ice, dust and rocky bodies that make up our Solar System."

While most carbon atoms in the cloud are locked away as carbon monoxide, around one in every hundred or so of the remaining molecules are pyrene.

"Imagine the thousands of different molecules that are out there, nearly all of them with many different carbon atoms in them, and one in a few hundred is in pyrene," says McGuire.

"That is an absolutely massive abundance. An almost unbelievable sink of carbon."

news.mit.edu

Environmental concerns over Starlink

SpaceX's communication network vastly outnumbers all other satellites

A group of 120 concerned researchers have written to the US federal government to raise concerns over plans by SpaceX to launch thousands more Starlink satellites.

Since 2019, the spaceflight company has launched over 7,000 satellites to create a global communication network. Once their useful lifespan has run its course, these are due to be de-orbited into our atmosphere, where they will burn up. While this has been a standard way of disposing of space hardware for many years, there are currently twice as many Starlink satellites as all other satellites put together.

The environmental concerns add to those raised by astronomers worried about how the bright satellites impact astronomical observations.

ILLUSTRATION

The letter urges caution about the impact of megaconstellations

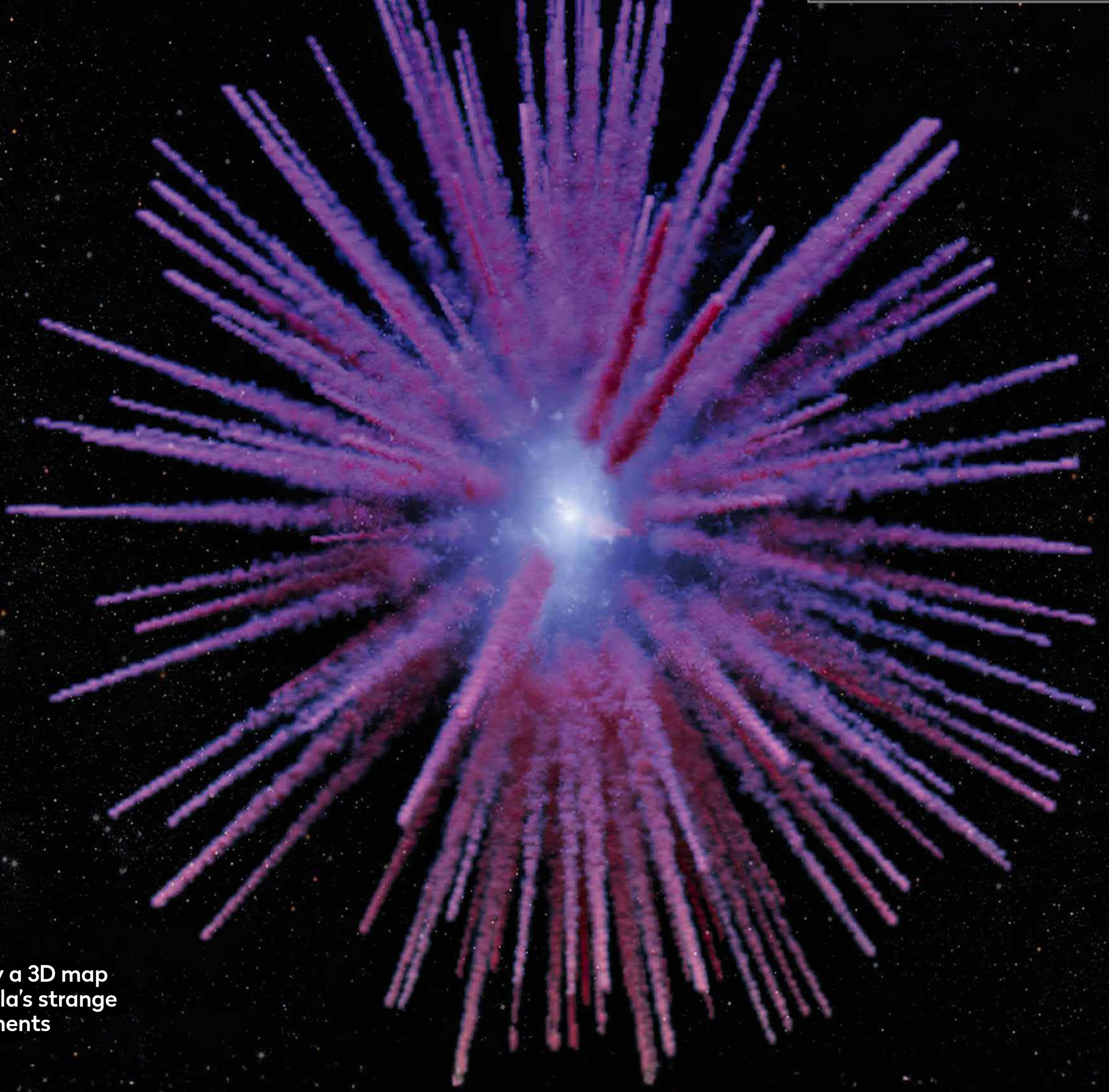
SpaceX is currently licensed to launch 12,000 satellites, but has requested that the Federal Communications Commission allow them to launch another 20,000. The letter from researchers, released in November 2024, asked the FCC to conduct an environmental review to assess the impact of the satellites.

"The environmental harms of launching and burning up so many satellites aren't clear," the letter states. "We shouldn't rush forward with launching satellites at this scale without making sure the benefits justify the potential consequences of these new megaconstellations being launched, and then re-entering our atmosphere to burn up and create debris."

www.pirg.org

FIVE COLLEGE RADIO ASTRONOMY OBSERVATORY (FCRAO), GOPAL NARAYANAN/MARK HEYER, YUCELYILMAZ/ISTOCK/GETTY, W. M. KECK OBSERVATORY/ ADAM MAKARENKO, X-RAY: (CHANDRA) NASA/CXC/U. MANITOBA/C. TREYTURIK/(XMM-NEWTON) ESA/C. TREYTURIK; OPTICAL: (PAN-STARRS) NOIRLAB/ MDM/DARTMOUTH/R. FESEN; INFRARED: (WISE) NASA/JPL/CALTECH/; IMAGE PROCESSING: UNIV. OF MANITOBA/GILLES FERRAND AND JAYANNE ENGLISH

▶ Pa 30 is the firework-like leftovers of a star that exploded 844 years ago



There's now a 3D map of the nebula's strange spikey filaments

ILLUSTRATION

Dandelion supernova

Astronomers shed new light on an ancient star explosion

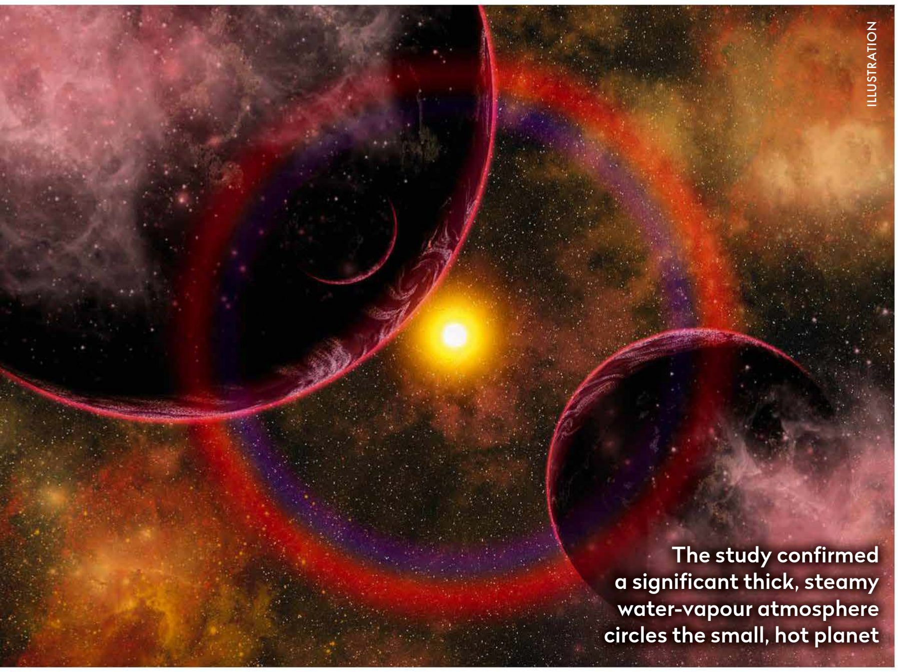
In AD 1181, a bright new star burst into life in the constellation of Cassiopeia, burning brightly for six months. We now know it was a supernova, the remnant of which wasn't identified until 2013, when it was linked to nebula Pa 30.

Astronomers a decade later discovered that the nebula contains filaments of gas and dust stretching outwards like the seeds of a dandelion. Using observations from the Keck telescope in Hawaii, scientists have now created a 3D map of the exploding supernova that tracks both the trajectory and the speed of the spikes.

"We find the material in the filaments is expanding ballistically," says co-lead author Tim Cunningham, a NASA Hubble Fellow at the Center for Astrophysics, Harvard and Smithsonian. "This means that the material has not been slowed down nor sped up since the explosion. From the measured velocities, looking back in time, you can pinpoint the explosion to almost exactly the year 1181."
www.keckobservatory.org

Our experts examine the hottest new research

CUTTING EDGE



The study confirmed a significant thick, steamy water-vapour atmosphere circles the small, hot planet

Steam world is under pressure

Study finds a planet rich in water, despite being too hot to form rain

The GJ 9827 system about 100 lightyears away in the constellation of Pisces contains three known super-Earth planets orbiting a nearby K dwarf star. With a mass almost twice that of Earth, GJ 9827 d is the largest of the triplets and also has the widest orbit. The innermost two companion worlds are very dense and so are thought to be predominantly rocky planets, but GJ 9827 d has a lower density, meaning it probably contains a significant amount of 'volatiles' like water, and possibly a thick atmosphere.

GJ 9827 d orbits relatively closely to its sun and has a calculated temperature of some 350°C (662°F). This implies that its atmosphere – contrary to most similar-sized planets – can't be dominated by hydrogen, as its high temperature would mean that such light gases would quickly escape. Previous observations of the planet have only lent support to this expectation by failing to detect any hint of hydrogen or helium streaming away from the planet.

The problem is that just knowing the density alone of a planet like this doesn't allow astronomers to work out what its atmosphere is like. Though the bulk has escaped, some of the hydrogen might still be retained as a thin envelope of hydrogen around the planet. Or it could have a thicker atmosphere of heavier gas molecules mixed in with some hydrogen.

To understand exactly what's going on, what's needed is someone spectroscopically analysing the atmosphere to try to directly detect the gas molecules that make it up.

Though clouds can really hamper such observations of worlds like this one, because they block views of the lower atmosphere, observations by the Hubble Space Telescope in 2023 indicated that molecular features can be detected for this planet. The much better capabilities of the James Webb Space Telescope (JWST) ought to be able to reveal GJ 9827 d's atmospheric composition.

Heavy weather

During her PhD in the department of physics at the University of Montreal, Caroline Piaulet-Ghorayeb attempted exactly that. She used the near-infrared spectrometers on JWST to observe GJ 9827 d for two transits across its sun, the starlight filtering through its atmosphere.

Piaulet-Ghorayeb and her team saw the clear spectral fingerprint of water molecules in the planet's atmosphere. In fact, Piaulet-Ghorayeb calculates that water vapour makes up at least 30 per cent of the atmosphere.

> ***"The planet is hot enough that this water wouldn't condense into liquid droplets in the atmosphere or on the surface"***

GJ 9827 d is a volatile-rich 'steam world'. The planet is hot enough that this water wouldn't condense into liquid droplets in the atmosphere or on the surface. Instead, at higher pressures the water would be in a supercritical state, where it mixes well with hydrogen gas. And despite the high temperature of the planet, this thick atmosphere made of heavier molecules would be stable. This is consistent with the non-detections of escaping hydrogen or helium.

Piaulet-Ghorayeb and her colleagues say that further planned JWST observations of the planet ought to be able to detect other constituents of the GJ 9827 d atmosphere, such as carbon monoxide or carbon dioxide, and possible sulphur dioxide. And this will help researchers understand how this planet formed with such a volatile-rich atmosphere.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *JWST/NIRISS reveals the Water-rich "Steam World" Atmosphere of GJ 9827 d* by Caroline Piaulet-Ghorayeb et al.
Read it online at: arxiv.org/abs/2410.03527

MARK STEVENSON/STOCKTREK IMAGES/GETTY IMAGES, MICHELLE LOCHNER/MEERKAT

How AI can aid astronomers

Humans and machines are teaming up to tackle huge datasets

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

With massive new surveys like the upcoming Vera Rubin Observatory, which is due to begin full science operations in August 2025, astronomers are worrying about how to cope with the upcoming deluge of data. Personally, I'm particularly excited about how, among the terabytes of images it will produce every night, we're going to find the really unusual and unexpected.

A new research paper might provide the answer, describing a tool that makes creative use of modern artificial intelligence to guide astronomers to interesting objects. As a test of their method, Michelle Lochner and Lawrence Rudnick set out to explore data from the South African radio telescope MeerKAT, which spent 6–10 hours staring at each of more than 100 galaxy clusters, together containing more than 6,000 radio galaxies.

How do we decide which galaxies to focus on? That's where a piece of software that the team call 'Protege' comes in. At its heart is a machine-learning routine called BYOL. BYOL takes a set of images and reduces them to a set of features. We could imagine doing the same trick with a stack of images of animals. There, it might be useful to have one feature that represents a rectangular shape, for the animal's body. And maybe something that looks like a leg. Other features might represent stripes or spots, or the shapes made by trees in the background. Choose enough features and you could represent any image as a combination of these individual elements.

Cyber-sorting the stars

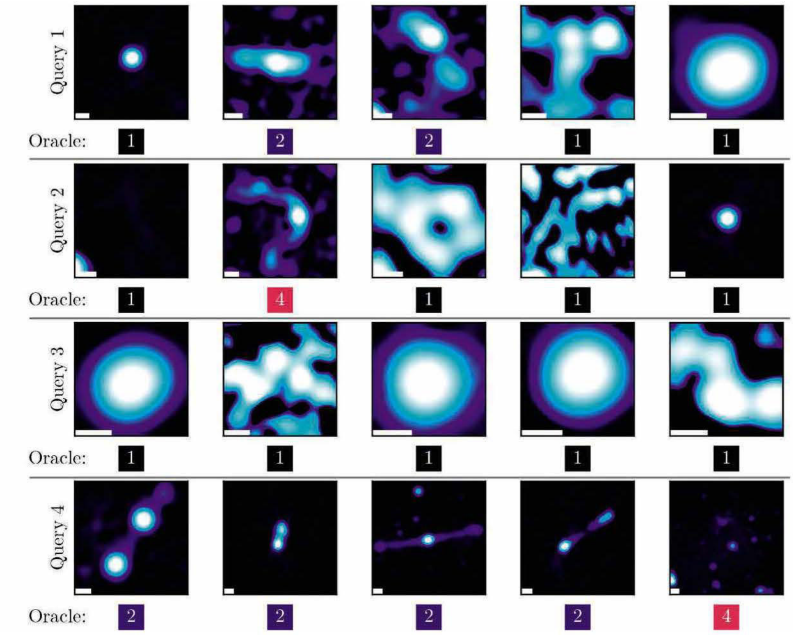
The magic of routines like BYOL is that you don't need to define the features yourself, as they're discovered by the network during a process of training. Some of the features it chooses might have meanings that make sense to humans, but others may be very abstract. The crucial thing is that similar galaxies should be represented by similar sets of features, and so thinking like this lets you find similar galaxies – they're the ones with similar features.

> **"Protege finds things its trainers missed, but it also identifies a fascinating and unexpected set of X-shaped sources"**

What's exciting is what happens next. Protege shows a random set of images to the astronomer who is using it, who ranks them on a scale of 1 to 5 based on how interesting they are. Using this input, Protege guesses what score images with a particular set of features are likely to get and uses this to decide what to show the astronomer for the next round of review. These too are scored and the process repeats until the astronomer is shown only things they find interesting.

Of course, what is considered 'interesting' will vary from astronomer to astronomer, but in the MeerKAT example, Protege does find things its trainers missed – galaxies surrounded by background emission, for example – but it also identifies a fascinating and unexpected set of X-shaped sources. Some of these seem to be systems where radio jets extend on both sides of the galaxy, but others, with long and sometimes faint 'wings' leading away from the central source, are much more confusing.

Even this example study, with 'just' 6,000 sources, has produced a set of galaxies we'd love to know more about. When Protege and its robot friends are set loose on those large datasets that are coming, who knows what we'll find?

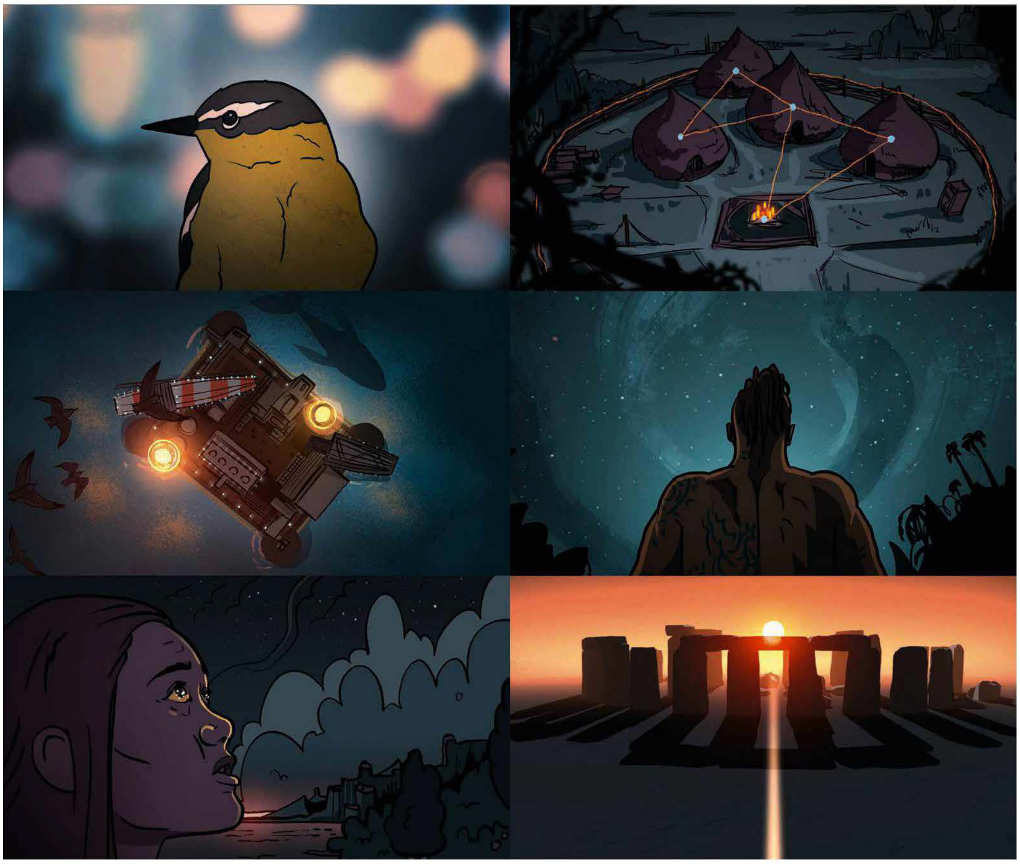


▲ In just a few training steps, Protege combed through thousands of galaxies, uncovering unusual circular and filamentary structures its humans had missed

Chris Lintott was reading… *Astronomaly Protege: Discovery Through Human–Machine Collaboration* by Michelle Lochner and Lawrence Rudnick
Read it online at: arxiv.org/abs/2411.04188

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



▲ **Smyth loves using art to break down difficult concepts. You can watch the animation for the 'Ancestral Skies' episode at bit.ly/astroanimation**

When you're trying to tell the story of the Universe, it helps to have some visuals. **Oliver Smyth**, animation director on *The Sky at Night*, explains how graphics bring complex cosmic mysteries to life

I'm currently thanking my lucky stars. At age 15, there was an apparent stark gulf between the arts and the sciences. Perhaps you can relate: are you team Bunsen burner or paint brush? Telescope or potter's wheel?

Working recently with *The Sky at Night* TV show and the Royal Society, I've been able to have my cake and then eat yet more cake… with extra sprinkles.

After many years in the arts – animating, directing, colouring in, playing with stop-motion puppets and telling stories with plasticine and crayons – I found myself consulting with world-leading scientists, cosmologists and most recently astroarchaeologists. The objects that created this wonderful alignment were the stars themselves. I was asked to make a short stand-alone animated film that would also be used in segments on the 'Ancestral Skies' episode of *The Sky at Night*. The theme was to be our connection to the night sky. A broad subject when considering ancient cultures, all living creatures, light pollution and our place in the natural world. Where to begin?

I must admit my natural tendency was to lean towards the esoteric, but luckily (perhaps for the audience) more level heads supported the vision of a film with feet on the ground but with eyes firmly fixed towards the stars. There were, as ever, constraints on time, budget and the sheer amount of information we could convey. But, as I've often found, good things can come from strict parameters.

The first port of call was an inspiring conversation with Clive Ruggles, emeritus professor of archaeoastronomy at the University of Leicester. This really was a treat. He not only conveyed a wealth and breadth of knowledge on this complex subject, but also used fantastic visual metaphors I knew instantly had to be in our film. One example is how the pattern of stars seen meeting the horizon could be memorised like musical motifs by ancient Polynesian navigators.

Making movie magic

This is where the power of animation to convey complex concepts in a way that's memorable and accessible really comes in. As the old saying goes, a picture is worth a thousand words. I believe this is especially true in the realm of science. Who can bring Newton to mind without thinking of an apple falling from a tree or a prism of rainbow light? In our innately storytelling brains, these are the ways in, allowing us to access the nuts and bolts of often complex information.

In truth, I've now made quite a few films and documentary segments in the general area of science. Be it illustrating global population data, explaining the effects of the new R21 malaria vaccine,

OLIVER SMYTH/BBC X 6, NASA/JPL-CALTECH, NICOLA FOX

or our previous *Sky at Night* film, *Five Mysteries of the Universe*, with Carlos Frenk from Durham University. It's my personal belief that seeing very human, hand-crafted images is particularly suited to this task – especially now at the dawn of the AI revolution.

With such highfalutin theories in mind, we made a conscious effort to keep everything in this film feeling hand-drawn and textural. It's becoming surprisingly easy for animators and visual effect folk to make near-photorealistic planets, stars, science instruments, and so on. But the closer to reality you go, the further away from impactful visual metaphor you can find yourself. Not to mention the fact that extreme realism can lead to a minefield of potential inaccuracies. On this project, we made a very considered but somewhat stylised model of Stonehenge. This technique means we can convey general theories about solstitial alignment without people writing in to complain "you misrepresented the fourth notch of the east quadrant arching stone".

And so with great support from *The Sky at Night* programme team, Beth Jinkinson at BBC Ideas, animation producer Ceri Barnes and talented fellow animator Heather Gretton, we created a short ditty that seems to have put smiles on faces. So that's good. Time for more cake, I think.

Oliver Smyth is a multi-award-winning director and animator with 18 years of industry experience

Looking back: The Sky at Night

20 November 1980

A week before the 20 November 1980 episode of *The Sky at Night*, NASA's Voyager 1 flew past Saturn, inspiring Patrick Moore to look at what the spacecraft had learned.

Voyager 1 left Earth in 1977, beginning its long flight into the outer Solar System. After a fly-by of Jupiter in 1979, it made its way to the ringed planet, beginning its observations on 22 August 1980, 109 million km (68 million miles) away. As it drew closer, it took detailed images of the rings, revealing their delicate structure in unprecedented detail, as well as three new Saturn moons (bringing the total at the time to 15; today, there are 146 known moons).

Voyager 1's trajectory was chosen to give a closer look at the largest of Saturn's moons, Titan, which was thought to possess a significant atmosphere. On 12 November, Voyager 1 passed just 6,492km (4,034 miles) from Titan, confirming it had a nitrogen atmosphere with 10 per cent methane and traces of other hydrocarbons. The surface pressure was only 60 per cent greater than Earth's at sea level, but the temperature was a very un-Earthlike –180°C (–293°F).

But getting close to Titan meant that Voyager 1 passed 125,500km (78,000 miles) above the cloud tops of Saturn's southern pole, slingshotting it out of the Solar System's plane, preventing it from passing any other planets. It continued outwards, however, eventually passing into interstellar space in 2012, where it continues to observe to this day.

▲ One of Voyager 1's spectacular shots from Saturn's dark side, November 1980

Explore the cosmos with BBC Sounds

While we wait for *The Sky at Night* to return to our screens, there are plenty of space-themed audio series and podcasts to listen to on BBC Sounds. Search for the 'Space' collection to find a whole host of radio documentary series about all things space – from cosmology to the future of human spaceflight. Or learn what *Desert Island Discs* were chosen by NASA's head of science, Nicola Fox. Plus there are dozens of astronomy-themed episodes of BBC radio favourites such as *In Our Time*, *The Life Scientific* and *BBC Inside Science*.

BBC
DESERT ISLAND DISCS
4

▲ Find out what NASA science chief Nicola Fox picked as her castaway tracks

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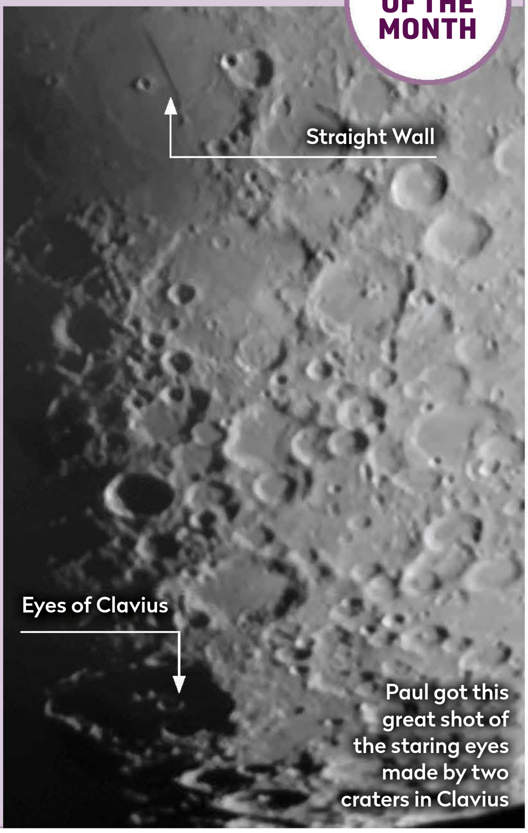
Out of the shadows

MESSAGE OF THE MONTH

Thank you for suggesting that Moon viewers look for the Eyes of Clavius, and for giving the date and approximate time to look (Sky Guide, November issue). I didn't know about this lunar clair-obscur effect before, but thanks to you I decided to take a look late in the afternoon on 9 November 2024, and there it was. In my image (right), north is up, and I also caught the shadow of the Straight Wall (Rupes Recta) as a bonus. Thank you again for bringing knowledge and pleasure to those who look at the skies.
Paul Lahti, Massachusetts, USA

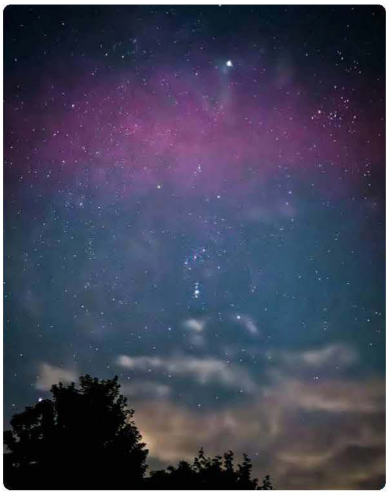
Delighted to hear you caught the Eyes of Clavius, Paul! Clair-obscur effects on the Moon don't hang around for long, as they depend on just the right amount of sunlight streaming over the lunar horizon. Well done for getting the timing just right. *– Ed.*

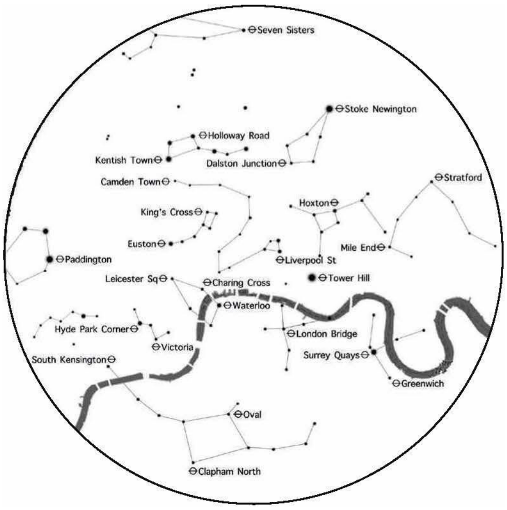

Straight Wall
Eyes of Clavius

Paul got this great shot of the staring eyes made by two craters in Clavius

Tweet

M.Wilson_Astrophotography
@mwilsonastro • 28 October
The aurora over Orion.
#orion #orionconstellation #aurora #northernlights #milkyway #universe @skyatnightmag

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Greenwich
Oval
Clapham North

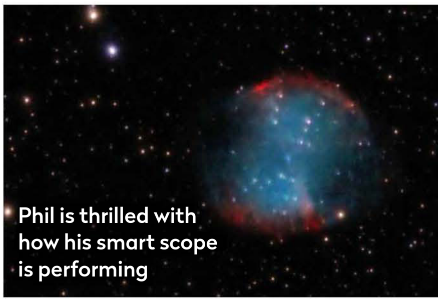
▲ **Return ticket to Pegasus, please! Tube stations become stars on David's map**

Capital idea

While working on a light-hearted personal project, I found myself imagining what it might look like if the Milky Way were mapped along the River Thames. I wondered, too, which stars might align with the locations of various Tube stations. It's a whimsical idea, but it raises interesting possibilities for connecting astronomy with London's geography! I thought my fellow readers might enjoy seeing this.
David Utting, via email

Level up

I am the proud owner of a Unistellar eVscope 2. There was an interesting update last month which enhanced the images taken. Here (above) is an image of the Dumbbell Nebula taken by me using the enhanced mode. This image has had no processing as such and is presented as it was, straight from the scope. I thought fellow readers might be interested.
Phil Schneider, via email



Phil is thrilled with how his smart scope is performing

Hidden depths

Unless I missed something, I have never seen a picture or illustration of a 3D image of a black hole. If a black hole consumes ▶

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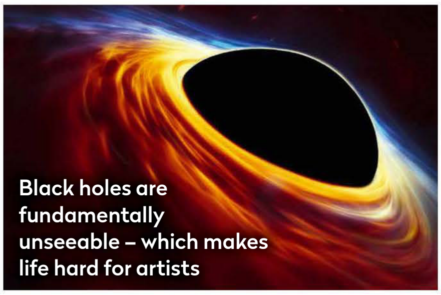
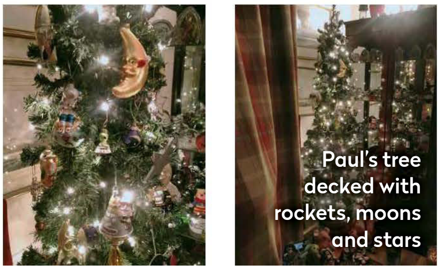
▶ material, which is 3D, then surely it doesn't convert it into 2D. Black holes must have a thickness?
Bill Foote, Weymouth

According to general relativity, black holes are spherical and smooth 3D objects. When it comes to illustrating them, however, their 3D nature is impossible to represent like, say, a picture of planet Earth, because light cannot escape a black hole, so our eyes would only see a textureless void. One way that illustrators get around this is by showing a black hole with a 3D accretion disc. ***– Ed.***


Black holes are fundamentally unseeable – which makes life hard for artists

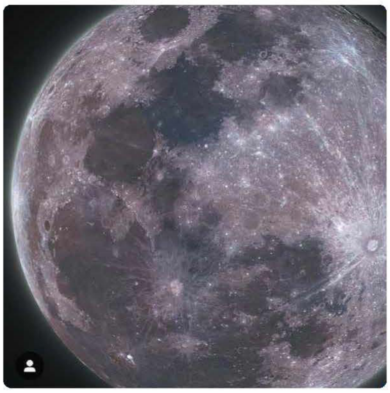
Festive fir-mament

I read with amusement the phrase "who says astronomy and Christmas can't mix?", in relation to the Ringed Planet bauble you featured in your last issue (Gear, December 2024 issue). It certainly can and does in our house, as you can see from our dedicated astronomy tree. This is one of many themed trees in our household, as my wife and I are Christmas mad.
Paul Adamson, Othery, Somerset


Paul's tree decked with rockets, moons and stars

Instagram

scollinsastro • 17 November
November full Moon.
100 frames per red/green/blue filter through the Esprit 150 telescope.
@bbcskyatnightmag



SOCIETY IN FOCUS

Fordingbridge Astronomers was founded in 2012 by four local enthusiasts meeting in a local pub. Since then, the club has grown dramatically and we now have members from all over Hampshire, Dorset and south Wiltshire.

Our monthly meetings, held at the Elm Tree in Ringwood on the third Wednesday of every month, are an essential part of what we do, with a range of astronomy talks by guest speakers and members. They're hosted online too, so everyone has a chance to enjoy them. We also arrange workshops about equipment and software, and regular stargazing meet-ups at our club observatory or one of our observing locations around the area. Our mission is to be approachable and friendly. No question is too simple!

We held a 'Messier marathon' in March 2024 that saw several members attend and a total of 81 Messier objects recorded.

Fordingbridge Astronomers taking on a Messier marathon in the New Forest last year

We also hold outreach events and attend local fairs, where we show the public how to safely observe the Sun.

Our members use Discord and WhatsApp to keep in touch and share hints and tips, and we use Instagram and YouTube to share images and updates with anyone interested in the night sky. Two of our members also do a monthly radio broadcast, 'Starry Skies' on Forest FM 92.3. Recordings are available on the Fordingbridge Astronomers YouTube channel.

▶ **www.fordingbridgeastro.org.uk**

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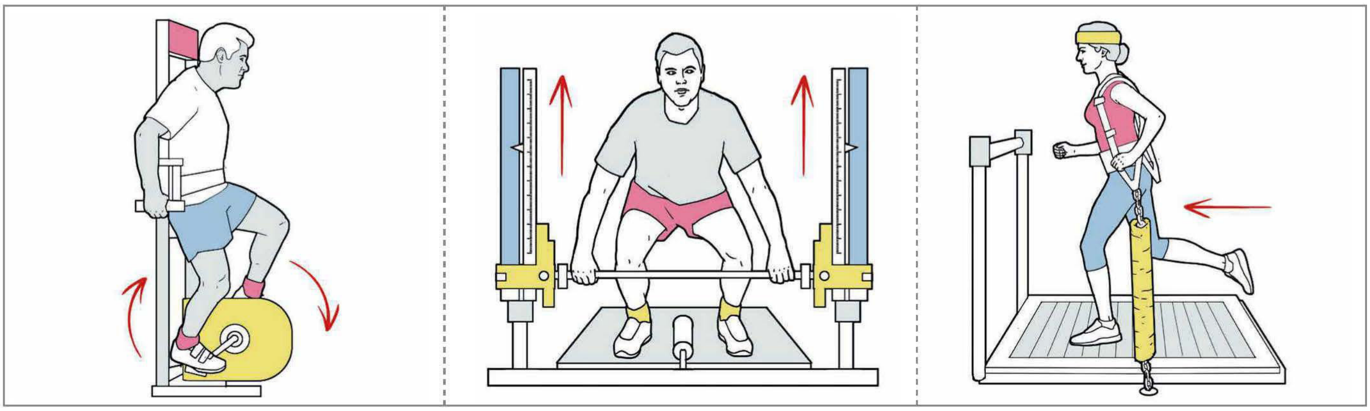
FIELD OF VIEW

Space: the final frontier for health

Human space travel is limited by one thing, says **Jonathan Powell** – the human body



▲ **How astronauts on the ISS stay healthy (left to right): the Cycle Ergometer with Vibration Isolation and Stabilization System (CEVIS); the Advanced Resistive Exercise Device (ARED); and the T2 Combined Operational Load Bearing External Resistance Treadmill (COLBERT)**

SON OF ALAN/FOLIO

Before Yuri Gagarin and that first generation of astronauts breached Earth's atmosphere to start a new era in space, nobody really knew just how humans would fare, either mentally or physically, in low Earth orbit.

In those early days, data was collected from probes and a selection of animals, but until that pioneering generation flew, no one could say how astronauts would react. The medical profession is still researching the effects of space on the body today, both when in space and the after-effects upon returning to Earth.

Of all the medical challenges facing life in space, the most fundamental remains the effects of weightlessness. John Glenn, the first American to orbit the Earth said that he "found weightlessness to be extremely unpleasant".

Ironically for Glenn, it wasn't until an incident two years after returning from space that a more in-depth level of medical scrutiny was triggered. When Glenn sustained a head injury after a fall in a hotel bathroom, the dizzy spells he was suffering highlighted inner-ear issues he'd sustained while in space. Later, they raised further questions about his health and how weightlessness had affected it, such as the strain placed on cardiovascular and circulatory systems.

Since the 1960s, studies conducted on those who've spent time in space have revealed a whole range of medical concerns. One paper revealed that on missions lasting six months or longer, an astronaut will experience bone density loss that is equivalent to several decades of ageing. Combatting this is one of the reasons why crews on the International Space Station need to exercise for two hours every day.

Research has also confirmed changes to vision, a compromised immune system, digestive issues and elevated long-term cancer risks. Prolonged spaceflight could also lead to cognitive decline, plus the onset of depression and anxiety.

However, while Glenn's bathroom fall inadvertently sparked a series of rigorous investigations from ground-based doctors, tracking the health effects of space has moved to the environment that causes them – space itself – and the spacecraft and orbiting platforms where longer-term research can be carried out.

In the intervening years, there have been thousands of medical research projects on human health in space. For example, in 1989 two physicians on board Space Shuttle Atlantis (STS-34) sought to establish a link between cranial pressure and motion sickness. In 1995, Mir Principal Expedition 18 saw a joint US–Russian medical research project to investigate the effects of weightlessness. And in 2023, members of Expedition 70 on board the International Space Station monitored how weightlessness impacts the neck, shoulders and leg veins.

However, regardless of what space has thrown at us then and now, the driving force to overcome any potential medical problem remains unshaken: our existence as a species beyond the day when Earth's time is finally done, depends upon it. It's one thing to assemble the hardware to propel humankind to Mars and possibly beyond the Red Planet; the state of our health when we arrive is another.

Jonathan Powell is a freelance writer and broadcaster and the astronomy columnist at the *South Wales Argus*

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News

With brand-new spacecraft, unstoppable SpaceX, lunar eclipses and rare planetary phenomena, 2025 promises to be a big year for space

SPACE IN 2025

From a visit to an asteroid and a milestone in human spaceflight to two lunar eclipses and an unusually bright Mars, **Jamie Carter** looks ahead to 2025's space missions and observing highlights

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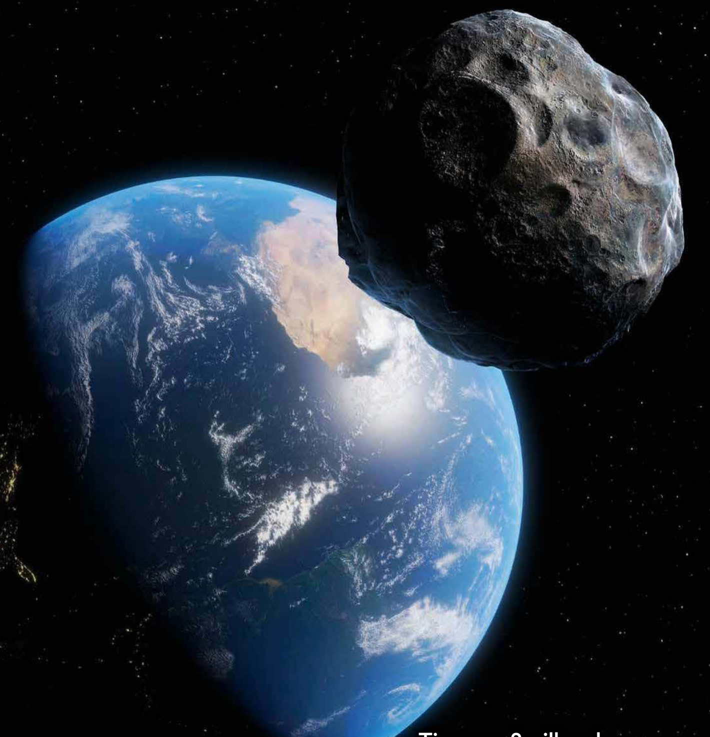
Asteroid sampling

China's ambitious mission will visit both an asteroid and a comet, returning samples to Earth

China's space agency, CNSA, will continue to progress in 2025 when it launches the follow-up to its debut Mars mission, Tianwen-1, which landed a rover on the Red Planet in 2021. Tianwen-2, scheduled to launch on a Long March 3B rocket in May, will be completely different, visiting a near-Earth asteroid and then a comet. Its first stop will be Kamoʻoalewa ('oscillating celestial object' in Hawaiian), a 40–100-metre (130–330ft) near-Earth asteroid that briefly went into orbit around Earth in 2024. It's the first mission to study a small asteroid, though scientists think Kamoʻoalewa may be a fragment of the Moon loosened by an asteroid striking its far side millions of years ago. The solar-powered Tianwen-2 will spend 2.5 years making close-up studies of the asteroid and also take a sample to return to Earth in a capsule that will parachute into China. Tianwen-2 will then travel to a comet called P/2013 P5 (PanSTARRS), reaching it in the 2030s.



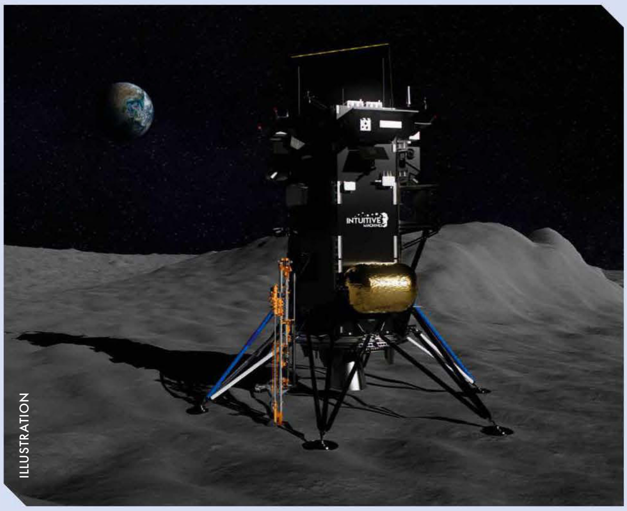
ILLUSTRATION

Tianwen-2 will make a touch-and-go grab for a piece of near-Earth asteroid Kamoʻoalewa

A second private lunar landing

The IM-2 lander will be the latest craft to set its sights on the lunar south pole

Private spaceflight company Intuitive Machines will make a second lunar landing attempt, in February 2025 at the earliest, with IM-2. The primary payload is a NASA experiment package, PRIME-1, that will investigate the feasibility of using lunar resources in situ, drilling lunar soil which it will analyse for useful materials such as water. The lander has been updated following the failure of the previous lander, IM-1, in February 2024. Turn to page 66 for more.



▲ Slated for early 2025, IM-2 aims to land near Shackleton crater and drill the surface to extract regolith for analysis

Artemis II crew Victor Glover, Reid Wiseman, Christina Koch and Jeremy Hansen

NASA shoots for the Moon

Humans are due to return to lunar orbit – provided there are no more delays

September 2025 is go time for NASA's first crewed mission to orbit the Moon in 53 years. A 10-day test flight, Artemis II will see one Canadian Space Agency astronaut and three NASA astronauts launch in an Orion capsule atop the agency's Space Launch System (SLS) rocket for the first time. Two million pounds of thrust will send the astronauts into two orbits of Earth before moving into a highly elliptical orbit, where they will experience a total eclipse of the Sun before going into lunar orbit. The mission is an essential test of hardware ahead of Artemis III, the first crewed mission to land on the Moon since Apollo 17 in 1972, which is planned for 2026. The bad news? The uncrewed Artemis I only launched in November 2022 after three months of delays, and NASA's official line is that Artemis II will launch "no earlier than" September 2025. Don't plan a trip to Florida for the launch just yet.

MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY, INTUITIVE MACHINE'S, CHANDAN KHANNA/GETTY, SNC, SPACE X

A 'space shuttle' visits the ISS

The Dream Chaser spacecraft hopes to provide another way to access low Earth orbit

Having welcomed its first astronauts on 2 November 2000, this year will mark 25 years of continuous habitation of the International Space Station (ISS). However, that landmark arrives amid uncertain times for the orbiting laboratory. It's only funded until 2030 and Boeing's stricken Starliner spacecraft – which in June 2024 suffered leaks and stranded two NASA astronauts on the station for several months – underlined just how much NASA and the ISS now relies on SpaceX. That could change in 2025, when Sierra Space's Dream Chaser Tenacity gets its chance to become NASA's second 'space taxi' when it launches atop a Vulcan Centaur rocket on an uncrewed cargo delivery mission to the ISS. The nine-metre-long (30ft) spacecraft, which looks like a mini Space Shuttle and also lands on a runway, is contracted to NASA for seven cargo delivery missions, but it can take up to seven astronauts. Its maiden voyage is pencilled in for May 2025.

ILLUSTRATION

Dream Chasers will take off like a rocket and land on a runway, like the old Shuttles

Unstoppable SpaceX may next try grabbing both the Starship and the booster in mid-air

SpaceX goes for a double catch

The company's Starship has developed at incredible speed

Spaceflight history was made in October 2024 when SpaceX launched its Starship Flight Test 5 from Starbase in Boca Chica, Texas. During the mission, the Starship spacecraft successfully entered orbit on top of a Super Heavy reusable booster rocket. A few minutes after lift-off that booster returned to Earth to be dramatically caught by mechanical 'chopsticks' – nicknamed 'Mechazilla' – on the launch tower. What will SpaceX do next? Details of Starship Flight Test 6, due in 2025, aren't yet clear, but according to Elon Musk, the CEO of SpaceX, engineers will next time try to have Mechazilla catch Starship as well as the booster. Until now, test flights have seen Starship crash or splash down in the Indian Ocean. SpaceX's lightning-fast development of Starship is impressive but also critically important for NASA, because Artemis III – the agency's upcoming crewed landing on the Moon – requires an adapted and tested version of Starship that can land on the lunar surface. ▶

Saturn 'loses' its rings

The planet's tilt will make them invisible from Earth for most of this year

Saturn's rings will disappear in 2025. The sixth planet's rings have been closing for a few years and in March they will become invisible from Earth until November. The phenomenon occurs because Saturn orbits the Sun every 29 Earth years and rotates on an axis tilted by 27°. Over the course of a Saturn year, it tilts away from and toward the Sun and experiences seasons, much as Earth does. Consequently, every 14-and-half years, Saturn's tilt aligns the rings with the line of sight from Earth, so we temporarily see them edge-on. Saturn will be lost in the Sun's glare in March, so it's not something to observe until it emerges in April and May, and then comes to its annual bright opposition on **21 September**. Long before that, on **4 January**, Saturn will be occulted by a crescent Moon in the southwest after sunset for European observers; from London, the planet will disappear at 17:21 UT to re-emerge at 18:32 UT. Just two weeks later, on **18 January**, Saturn and Venus will get to within just 2° of each other above the southwest horizon in the post-sunset sky, an event visible across the world.

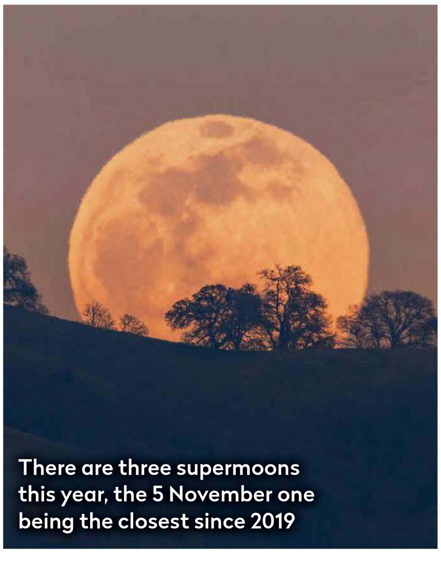
Saturn's rings have been gradually vanishing as the planet turns edge-on to us

A special year for Mars

The Red Planet will be extra bright at opposition

Seasoned observers will have noticed that Mars has been getting noticeably brighter and redder since October, the inevitable run-up to the planet's once-every-26-months opposition on **16 January**. The best time to observe the Red Planet since its last alignment with Earth and the Sun in December 2022, a planet's opposition sees its entire disc lit up, but it also means it rises in the east at sunset and sets in the west at sunrise. Be sure to observe it on **12 January** when it's nearest to Earth, when it should be at its brightest at magnitude –1.4. The next opposition of Mars will occur in February 2027. The brightness of Mars during 2025 also makes its conjunctions worth observing. On **13/14 January**, US astronomers will be treated to the near-full Moon occulting the planet, while UK viewers will witness a close pass on **13 January** and **9 February**. On **3 May**, Mars moves across the stars of the Beehive Cluster (M44) in Cancer.

▲ Mars has a lovely brush with the Beehive open cluster of stars on 3 May



There are three supermoons this year, the 5 November one being the closest since 2019

MICHAEL KARRER/CCDGUIDE.COMX 2, PETE LAWRENCE, SUNDRY PHOTOGRAPHY/GETTY, JAMIE COOPER/GETTY, ALAN DYER/STOCKTREK IMAGES/GETTY

Lunar highlights

The full Moon comes in for a close-up in 2025

In 2025, the Moon will get closer to Earth than at any time since February 2019, when a so-called 'supermoon' (technically referred to as a perigee syzygy Moon) on **5 November** sees our natural satellite just 356,833km (221,726 miles) distant. A lesser supermoon will rise on the months either side of that date, on **7 October** and **4 December**.

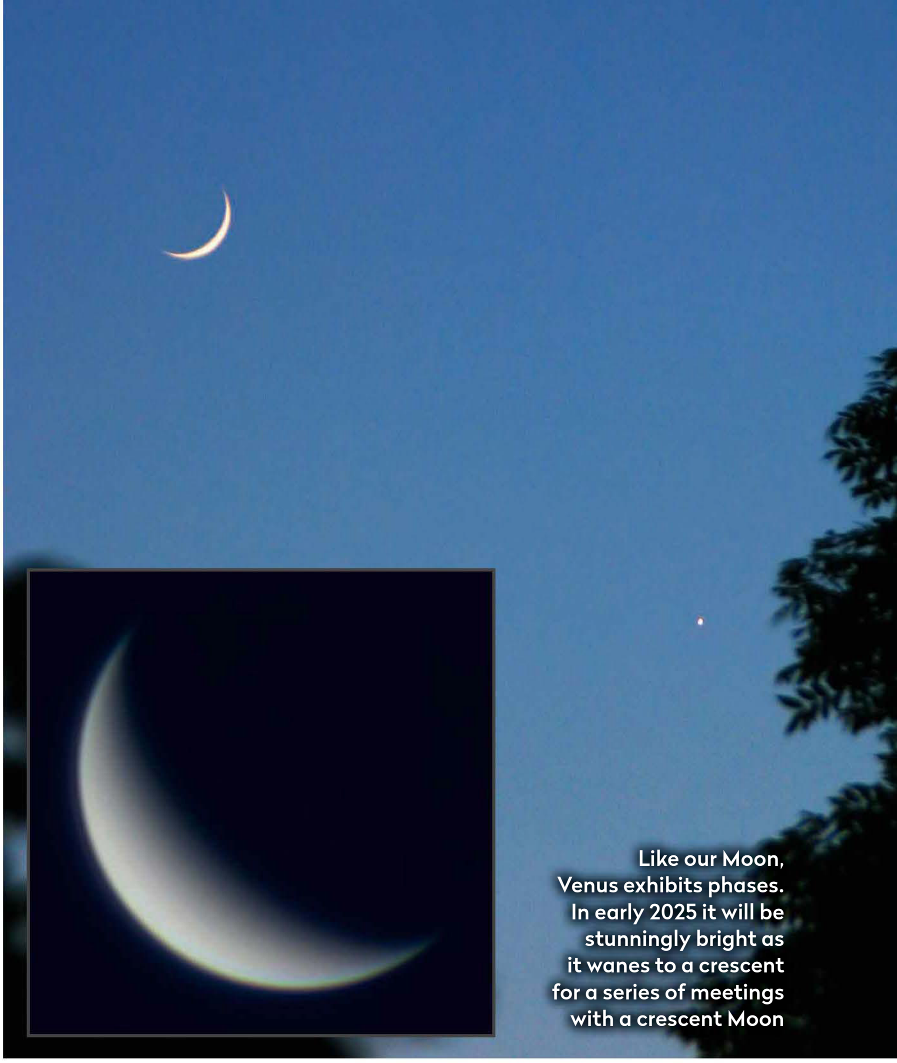
However, a 2025 highlight for astrophotographers will be the Moon repeatedly passing through the sparkling Pleiades open cluster of stars. Sadly, none will be easy to image. On **10 January**, **12 September**, **10 October** and **4 December**, bright near-full Moons will blast across the 'Seven Sisters' stars, making them challenging both to see and image.

However, from the UK, early risers on **23 June** may snag a view of a 7%-lit crescent Moon in the east, sitting plumb against the Pleiades. Other lunar highlights in 2025 include two post-sunset conjunctions with Jupiter in the west on **28 May** and in the east on **7 December**.

Venus rises and falls

Catch Venus next to the crescent Moon

The 'Evening Star', as Venus is called, will live up to its name on **16 February** when it reaches its greatest brilliance after sunset at a remarkable magnitude –4.8. Use a small telescope in the first few months of 2025 to see the phases of Venus change from being half-lit on **11 January** (its dichotomy) to an increasingly slim crescent. After that bright showing, Venus will rapidly sink into the Sun's glare, passing between Earth and the Sun (its inferior conjunction) on **22 March**. It will emerge as a brilliant 'Morning Star' before sunrise during April and quickly peak in brightness on **24 April**. During its evening apparition, it will be closely passed by a crescent Moon after sunset on **3 January**, **1 February** and **1 March**. See the same sight before sunrise on **22 June**, with Jupiter joining the fray on **21 and 22 July**, and **20 August**. On **19 September**, a 6%-lit crescent Moon will pass very close to Venus and Regulus.


Like our Moon, Venus exhibits phases. In early 2025 it will be stunningly bright as it wanes to a crescent for a series of meetings with a crescent Moon

▲ See the Moon redden as it moves completely into Earth's shadow – a total lunar eclipse – on 13/14 March and 7/8 September

A quartet of eclipses

Two total lunar eclipses will turn the Moon a deep red

After two total solar eclipses in seven years, in 2017 and 2024, North Americans may have thought their celestial luck had ended. Not quite. The coming year will see a partial solar eclipse on **29 March**. It's mainly visible in Europe and the Arctic, but eastern Canada and the extreme northeastern US will arguably get the best views. A big eclipsed sunrise will be observable if skies are clear from Boston (42% of the Sun's surface covered) and eastern Maine (83%) in the US and Québec City (72%) and Newfoundland (86%) in Canada, which will be a dramatic sight. In the UK, a small partial will be seen mid-morning, with London seeing 31%, Cardiff 35% and Edinburgh 41%. Aurora hunters in Iceland will see a 70% partial eclipse. 2025's second partial solar eclipse, on **21 September**, will be observed only from New Zealand and Antarctica.

Eclipse-wise, 2025 will be dominated by two total lunar eclipses, the first since 2022. On **13/14 March** and **7/8 September**, the full Moon moves through Earth's umbral shadow in space to create an eerie-looking, reddish lunar surface for a few hours. Both events will be technically visible from the UK during the moonset in the early hours of **14 March** and at moonrise on **7 September**. Observers in North America will get a fabulous view of the **13/14 March** event in true darkness, but miss out entirely on September's 'blood moon'.

Jamie Carter is a science and travel journalist, and edits WhenIsTheNext Eclipse.com

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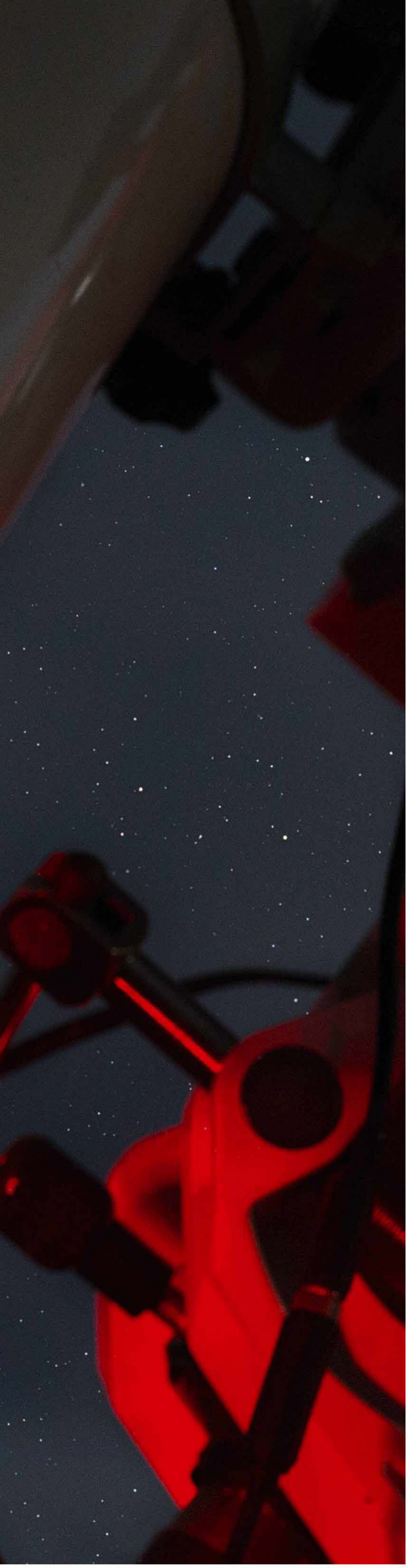
If you've ticked the planets off your list, here are the kit and tips you need to tackle beautiful nebulae and galaxies

PETE LAWRENCE



Jump into the DEEP end

How to progress from planetary to deep-sky photography

Love imaging the planets, but ready to try something new? **Charlotte Daniels** explains how to take the plunge and stretch your skills further

Perhaps the most common question beginners ask when they're starting out in astrophotography is: "What telescope should I buy?". The answer you'll almost always hear from astrophotographers is: "What sort of astrophotography would you like to do?".

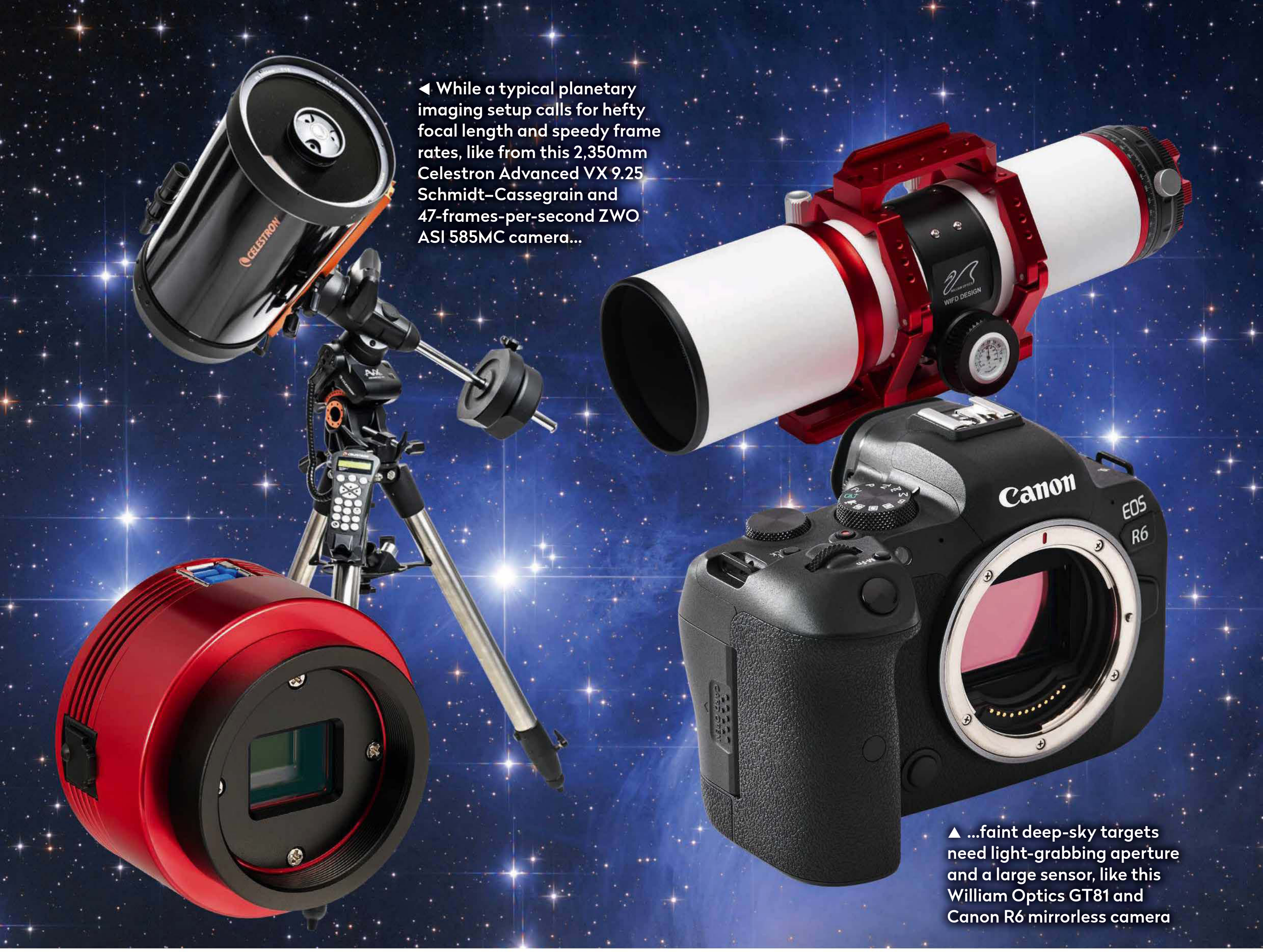
That's because there isn't a perfect one-size-fits-all telescope that answers the first question. Some models are simply better suited to planetary imaging than deep-sky astrophotography, the two main forms of astronomy imaging.

Planetary imaging – as the name suggests – involves photographing the Solar System's planets, but we also often include imaging our Moon in this bracket, as the equipment and capture requirements are very similar. Meanwhile, deep-sky photography encompasses objects such as star clusters, galaxies, nebulae and planetary nebulae.

The decision you make on the second question will determine the equipment you invest in. If you decide on planetary imaging, you'll likely end up with a very different setup to if you went after deep-sky objects (DSOs), especially considering that astrophotography is about more than just the telescope – it's also about the camera and the mount.

If you're in the camp who pursued the planets first, you may now like to try your hand at some deep-sky targets. After all, planetary astrophotography has unique challenges, including battling unpredictable atmospheric conditions and the limited number of targets. The planets don't always present themselves well; the best conditions for capturing the superior planets (those further out from the Sun than Earth is) are when they're high in the sky and free from the pollution that hangs near our horizon. And then there's the wait for planets to be at opposition, when they're at their largest and brightest, which doesn't always happen every year; Mars, for example, reaches opposition once every 26 months or so.

So, if you're ready to give imaging objects in the deep sky a go instead, we'll guide you through the different equipment requirements of both imaging types, what your planetary equipment might be capable of, and choosing a couple of DSOs to turn your telescope to for a first imaging run. ▶



◀ While a typical planetary imaging setup calls for hefty focal length and speedy frame rates, like from this 2,350mm Celestron Advanced VX 9.25 Schmidt–Cassegrain and 47-frames-per-second ZWO ASI 585MC camera…

▲ …faint deep-sky targets need light-grabbing aperture and a large sensor, like this William Optics GT81 and Canon R6 mirrorless camera

▶ To begin with, let's cover the basic requirements of planetary imaging setups versus deep-sky setups. What makes them so different? Appreciating the differences between planets and deep-sky objects helps explain why the equipment requirements vary: planets are bright, local sources, whereas deep-sky objects are faint and often unable to be seen with the naked eye.

Planetary setups

For a planet-grabbing telescope, focal length is key. We want a long focal length to bring the target as close as possible, meaning we're generally looking for something that delivers 1,200–2,000mm focal length. A telescope offering this in a compact design, such as a Maksutov– or Schmidt–Cassegrain (SCT), is a popular choice. Newtonian reflectors are sometimes chosen, but their focal length is slightly shorter. Meanwhile, Ritchey–Chrétien (RC) telescopes tend to be avoided by planetary imagers due to large central obstructions, despite their long focal lengths.

A long-focal-length telescope often means a high focal ratio (determined by dividing the focal length by the telescope aperture). The higher this number, the 'slower' the telescope: f/8 and upwards is often a desirable attribute for planetary telescopes, as it steadies the atmosphere and increases the chance of clear views. The focal length of the telescope can be increased with a Barlow lens: a 2x Barlow lens increases a 1,000mm telescope to 2,000mm, but also doubles its focal ratio. This makes planets appear larger, but also dimmer.

In addition to the telescope, the camera is perhaps what differentiates a planetary setup most from its deep-sky counterpart. Designated planetary cameras have small sensors to ensure planets fill as much of the frame as possible. These tend to take video rather than still images, to combat atmospheric or seeing conditions. A single static exposure will (unless the seeing is excellent) return a blurred photo, while 3–5 minutes' worth of video will capture thousands of frames, which can then be sifted with planetary stacking software to select the best ones to stack for a brighter, still, final image. Taking bursts of sub-1-minute videos is a popular approach.

In terms of the mount, many planetary imagers opt for an altazimuth type as they're easy to set up – these are also the mounts that are offered as part of a complete planetary setup by manufacturers, with a telescope included. Not only can we forgo polar alignment, but these mounts are perfect for short-exposure daylight photography too.

Deep-sky setups

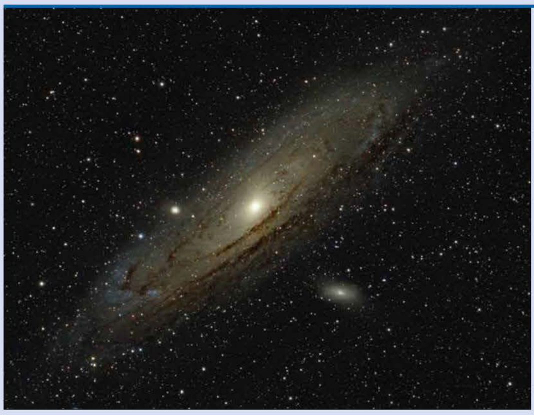
Deep-sky setups are very different. A compact refractor is generally best for nebulae and galaxies. They're lightweight and easy to use, yet offer crisp

LORAND FENYES/STOCKTREK IMAGES/GETTY, PLANETARY CAMERA: FIRSTLIGHTOPTICS.COM, @THESHED/PHOTOSTUDIO X 4, FRANZ KLAUSER/MANFRED WASSHUBER/CCDGUIDE.COM X 2, HORST ZIEGLER/CCDGUIDE.COM, MICHAEL DEGER/CCDGUIDE.COM

Try these for your first deep-sky image

The Orion Nebula

Designation: M42
Magnitude: +4.0
Apparent diameter: 1°
Best months to image: December to March



The Andromeda Galaxy

Designation: M31
Magnitude: +3.4
Apparent diameter: 5°
Best months to image: September to November

Bode's Galaxy and the Cigar Galaxy

Designation: M81, M82
Magnitude: +6.9 and +8.4
Apparent diameter: 21 and 11 arcminutes
Best months to image: All year

The Dumbbell Nebula

Designation: M27
Magnitude: +7.5
Apparent diameter: 8 arcminutes
Best months to image: July to November

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◀ Cooled CMOS cameras are dedicated to the task of clinching dim targets...

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MENU

...but a decent second-hand DSLR will do for starters, giving you control over ISO and timings

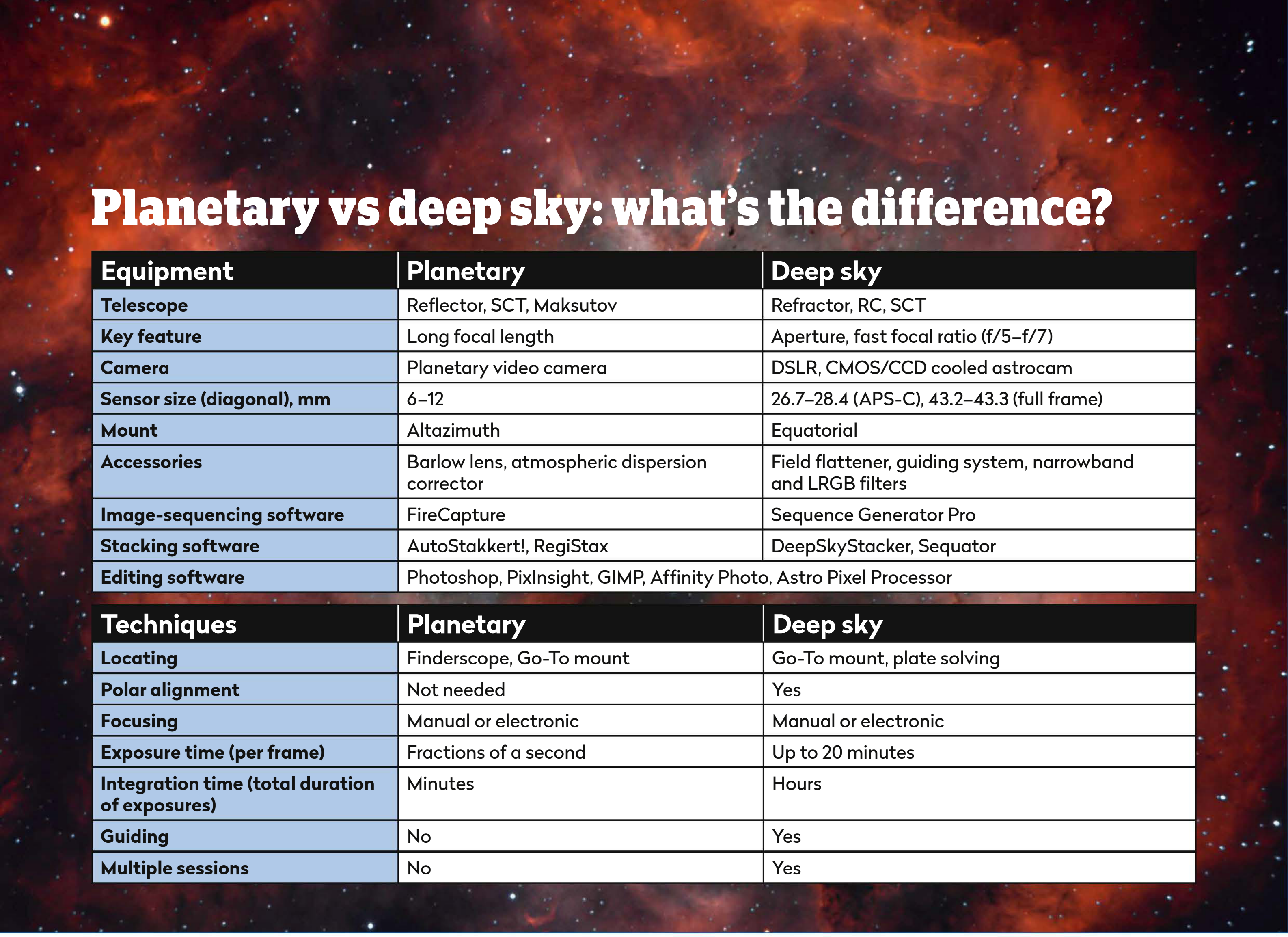
and high-contrast images due to quality glass lenses. Refractors also offer superior colour management to get the best from these delicate targets. Aperture is also key, as it boosts the light-gathering ability of the telescope and makes it more efficient.

Shorter focal lengths are generally more desirable: 400mm–700mm will provide the ability to capture a wide range of targets from the Messier and NGC deep-sky catalogues. A wide aperture and shorter focal length mean a lower focal ratio, or a 'fast' telescope: f/5–f/7 means a reasonably fast deep-sky refractor. Smaller focal ratios don't spread light out as much, so they deliver brighter images, which is exactly what is needed when capturing faint objects. In addition to refractors, RCs are excellent DSO telescopes as they combine high magnification, wide fields and fast focal ratios in a compact tube.

Ultra-sensitive cameras

Instead of using cameras that take video, deep-sky astrophotographers tend to use designated CCD or CMOS astro cameras: low-noise, cooled devices with large sensors and pixels, purpose-built for long exposures. Taking long exposures through traditional cameras introduces electronic and thermal noise into an image as the sensor starts to heat up. However, astro cameras reduce this through built-in cooling fans which keep the camera cool for longer exposure times. Depending on the sensor and its cooling abilities, these cameras can take exposures of up to (and even over) 20 minutes per frame.

A DSLR camera is also a popular deep-sky choice, as it has the functionality of a deep-sky camera but can be manually operated without a computer; we can easily change its light sensitivity (ISO) settings ▶



Planetary vs deep sky: what's the difference?

Equipment	Planetary	Deep sky
Telescope	Reflector, SCT, Maksutov	Refractor, RC, SCT
Key feature	Long focal length	Aperture, fast focal ratio (f/5–f/7)
Camera	Planetary video camera	DSLR, CMOS/CCD cooled astrocam
Sensor size (diagonal), mm	6–12	26.7–28.4 (APS-C), 43.2–43.3 (full frame)
Mount	Altazimuth	Equatorial
Accessories	Barlow lens, atmospheric dispersion corrector	Field flattener, guiding system, narrowband and LRGB filters
Image-sequencing software	FireCapture	Sequence Generator Pro
Stacking software	AutoStakkert!, RegiStax	DeepSkyStacker, Sequator
Editing software	Photoshop, PixInsight, GIMP, Affinity Photo, Astro Pixel Processor	

Techniques	Planetary	Deep sky
Locating	Finderscope, Go-To mount	Go-To mount, plate solving
Polar alignment	Not needed	Yes
Focusing	Manual or electronic	Manual or electronic
Exposure time (per frame)	Fractions of a second	Up to 20 minutes
Integration time (total duration of exposures)	Minutes	Hours
Guiding	No	Yes
Multiple sessions	No	Yes

▶ and exposure settings to suit our target. While these don't come with cooling systems in place, we can still comfortably take exposures from 30 seconds and over with them, even into the 3–5 minute range for some of the high-end models.

Image exposure length also depends on the mount. To maximise the duration of our frames, an equatorial (EQ) mount is a must. These have one axis aligned with the celestial pole, allowing us to track a target across the sky in an arc and keep it central in the image frame. A mount that's accurately polar-aligned lets us take exposures several minutes long or, by adding a guiding system, even longer.

Making switches to your kit

So, how can we make the transition from planetary to deep-sky photography? First, consider the telescope. If you're using a Newtonian telescope, you're off to a good start! Many are reasonably fast – a 1,000mm reflector with 200mm aperture has an f/ ratio of f/5. SCTs are also versatile enough to make the move from planets to DSOs, although they are likely to have a slower f/ ratio.

There are accessories to speed up sluggish scopes and ready them for deep-sky objects. It's time to ditch the Barlow lens and buy a focal reducer; these cause the light entering the telescope to converge at a steeper angle, leading to a wider field of view and reducing the focal length. As the telescope's aperture can't change, this reduces the f/ ratio. Not only do these make the telescope faster for DSOs, but they'll increase the number of targets you can fit into the field of view.

The next thing to do is to check your planetary camera's specification: how large is the sensor, and is it able to take still pictures in addition to video? If so, it could be that it is capable of some basic deep-sky images. If not, then a DSLR camera might be a sensible next purchase.

There's an excellent second-hand market for DSLRs, meaning you can pick up an entry-level model at a reasonably modest price. The key features needed are a Live View function for star focusing, a 'Bulb' mode that allows us to extend exposure times into minutes, and an adjustable ISO function.

Before making any accessory or camera purchases, check out a field-of-view calculator such as www.astronomy.tools and browse your favourite deep-sky objects. Check whether they'll fit into the field of view provided by your particular telescope and camera. This will help you to determine whether your current equipment (or planned purchases) will return the results you're expecting.

Askar V REDUCER

▲ You can speed up a sluggish scope with a focal reducer

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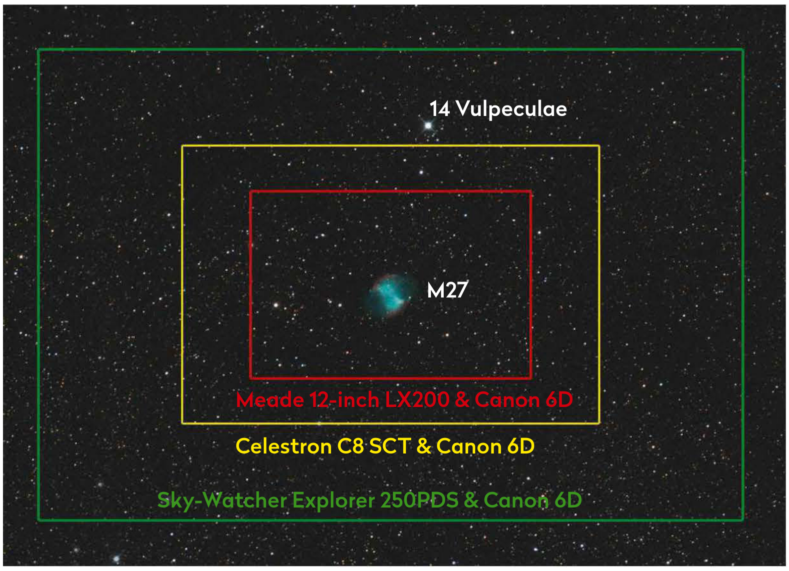
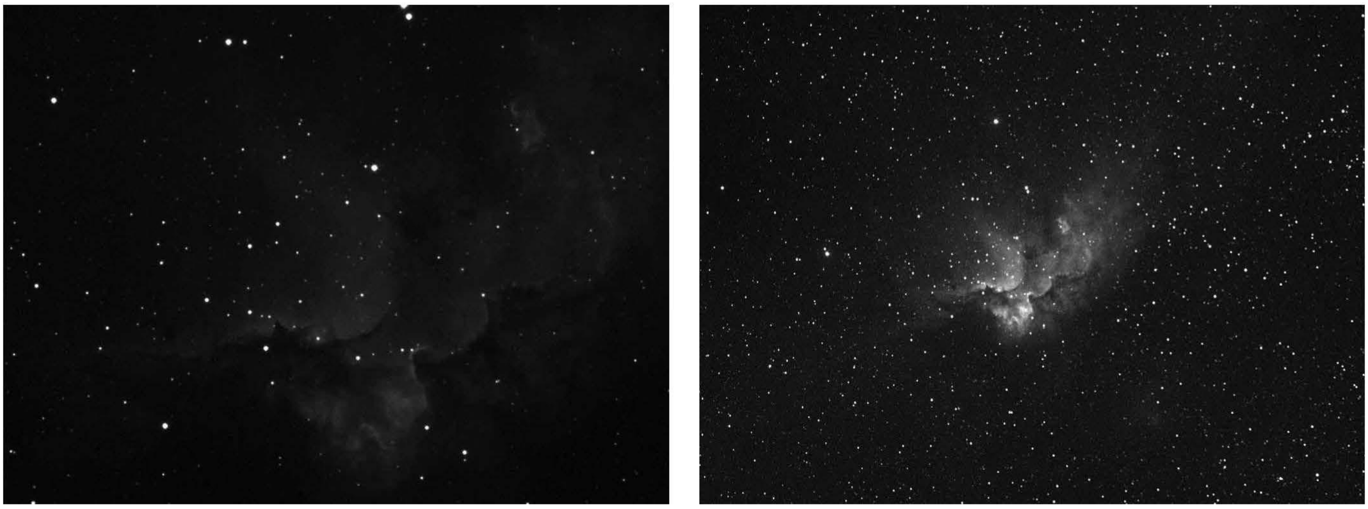
SAM GOWLAND/ISTOCK/GETTY, CHARLOTTE DANIELS X2


14 Vulpeculae
M27
Meade 12-inch LX200 & Canon 6D
Celestron C8 SCT & Canon 6D
Sky-Watcher Explorer 250PDS & Canon 6D

▲ **How the field of view of the deep-sky target the Dumbbell Nebula, M27, varies using three different scopes popularly used for imaging planets, from a relatively close-up view to a wider view that captures the surrounding starfield**

▲ **A mount that tracks with the sky over the long exposure times that faint targets require is a must. Without one, your stars will trail, as shown here**



▲ **The slower the telescope, the more time it takes to gather the same level of data as a faster telescope. Left: one 15-minute frame of the Wizard Nebula, captured using a Celestron 9.25-inch SCT, a 'slow' telescope with an f/ ratio of f/10. Right: the same camera and settings on a faster telescope, a William Optics GT81, which has an f/ ratio of f/5, produces a brighter, more detailed image**

If you have an altazimuth mount, the good news is that deep-sky imaging is possible. However, you'll be limited to sub-1-minute exposures to account for field rotation. Because altazimuth mounts don't align with the celestial pole, the field of view of the camera remains orientated on the horizon. This means over time, our view of the sky slowly rotates - long exposures will therefore show the stars trailing. You can maximise the possible exposure time by aiming for a target close to Polaris and the celestial pole; the closer to the celestial equator your object is, the greater the star trailing will be.

If your telescope is particularly slow and you don't have a reducer to hand, pick the brightest deep-sky objects to capture as much light as possible within these short frames. You can also combat the short exposure requirements of an altazimuth mount by bumping up the ISO setting on a DSLR camera, to pack as much light into each fame as possible. Image your target for as long as possible and then stack these images in a stacking freeware such as DeepSkyStacker or Sequator.

If you already have an equatorial mount, longer exposures are possible – but the focal length of a planetary telescope does complicate things. In addition to polar alignment, deep-sky imagers use guiding systems, comprising camera and software that corrects tracking errors during long exposures. The longer the focal length, the more pronounced these tracking errors are, so an off-axis guider will be required to keep stars pin-sharp.

Depending on your kit, some level of deep-sky capture should be possible. Temperamental weather can sometimes put a dampener on this rewarding hobby, but hopefully, by expanding your astronomy horizons and trying out new things, not only will you make the most of your kit, but you'll gain a deeper appreciation of our stunning skies.

Charlotte Daniels is an amateur astronomer, astrophotographer and journalist

Is there water on Mars?

Today, the Red Planet is a dry and arid place, but it wasn't always that way

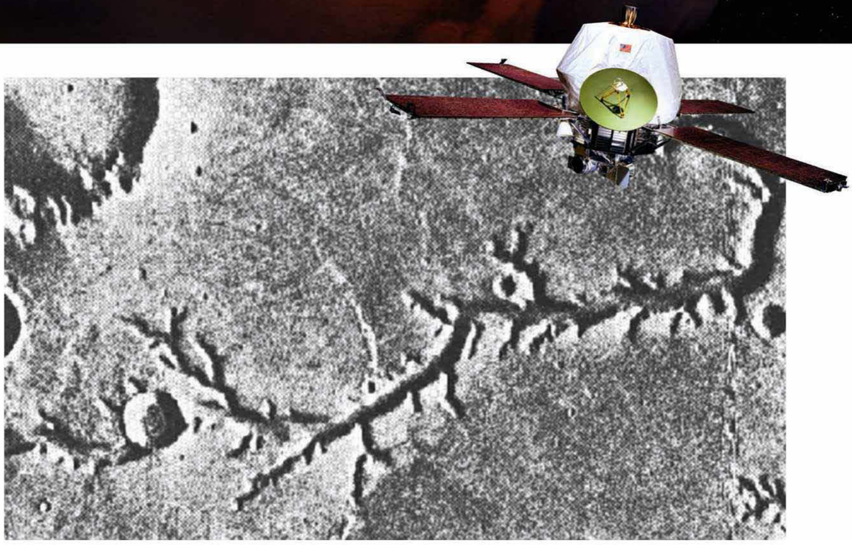
You've probably seen the online meme showing a glass of water balanced on top of a Mars chocolate bar, with the caption: "Water discovered on Mars!". It's very popular, but every time it's posted, amid all the laughter, someone usually responds cynically: "...again". They do have a point. The 'discovery' of water on Mars has happened so many times you'd be forgiven for thinking that the Red Planet is wetter than a Bank Holiday weekend. So what do we actually know about the waters of Mars, and will they be of any use to us in the future?

Long before the birth of the Space Age, there were a great many people who firmly believed that water flowed on the Red Planet. They knew Mars was probably a lot colder than Earth because it was further from the Sun, but they were sure Mars's water was liquid because through telescopes they saw dark areas that changed size over the seasons: believing these to be patches of vegetation, they assumed that there must be water to irrigate them. Astronomers like Percival Lowell (1885–1916) claimed to have observed a network of straight lines crisscrossing Mars and, adding 2 + 2 to get 100, he declared they were canals dug out of the ground by Martian navvies to carry precious water from the poles to thirsty cities.

Mars's hidden oceans

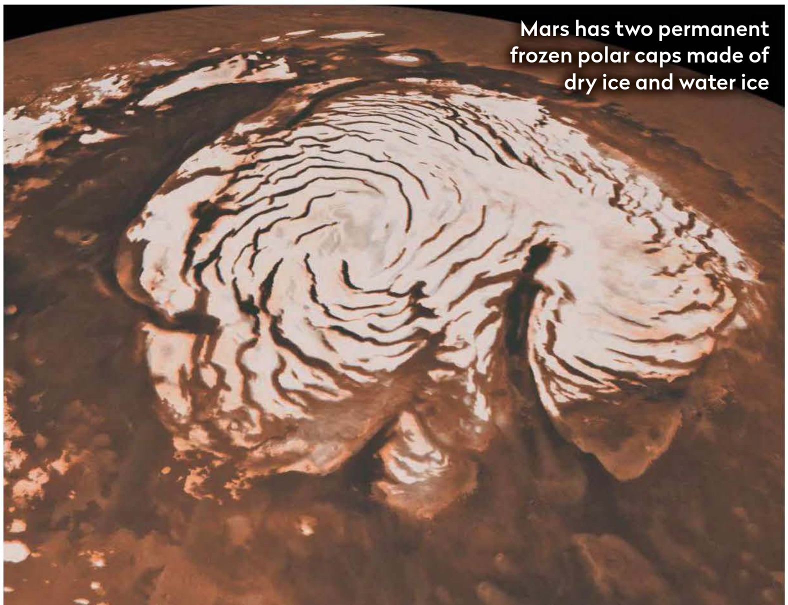
Then NASA's Mariner 9 sent back its first images in 1971 showing Mars was a frozen, cratered wasteland. The seasonal patches of vegetation were just vast fields of fine dust, blown away by seasonal winds to reveal the dark surface beneath, and the canals were nowhere to be seen. Mars was a dust bowl, drier and deader than the most arid desert on Earth.

But today, thanks to space missions that followed Mariner, we know that there is water on Mars. It's just not found on the surface in the liquid form we're most familiar with here on Earth. When human explorers eventually reach Mars, if they want to use its water, they'll have to dig.



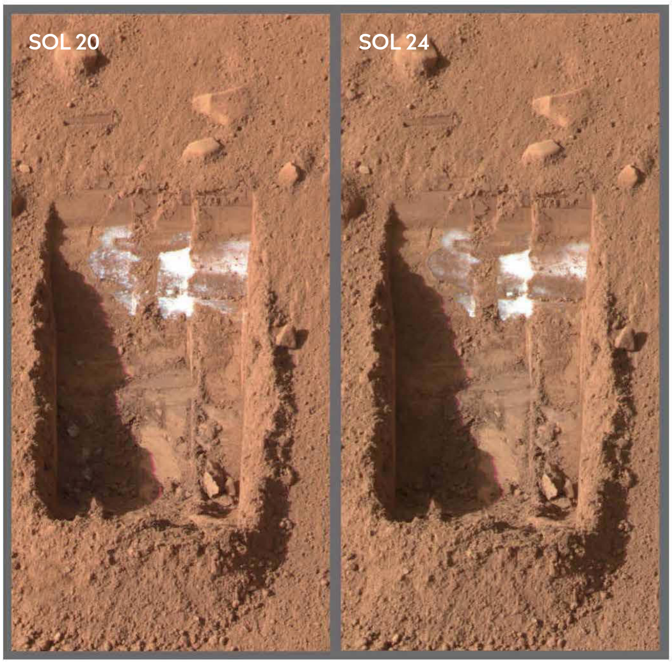
▲ Mariner 9, the first to orbit Mars, surprised scientists with images of ancient river beds

Large amounts of water ice have been discovered

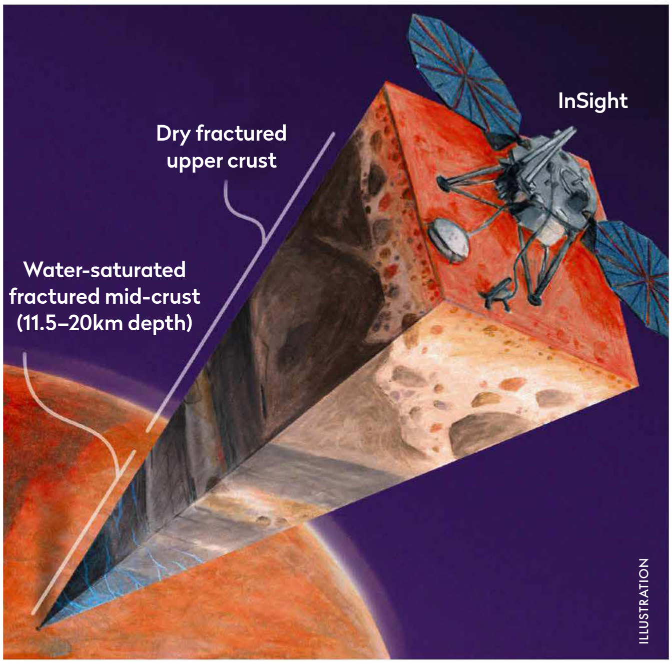


Mars has two permanent frozen polar caps made of dry ice and water ice

NASA/JPL, NASA/JPL-CALTECH, NASA/JPL-CALTECH/MSSS, NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/TEXAS A&M UNIVERSITY, JAMES TUTTLE KEANE AND AARON RODRIQUEZ, MARK GARLICK/SCIENCE PHOTO LIBRARY/GETTY



▲ Lumps (bottom left of trench) observed by NASA's Phoenix lander in 2008 evaporated four days later, confirming they were ice


InSight
Dry fractured upper crust
Water-saturated fractured mid-crust (11.5–20km depth)
ILLUSTRATION

▲ By listening to marsquakes, InSight found evidence for oceans' worth of water sandwiched between cracks deep underground

at the Red Planet's poles and beneath its surface at mid latitudes. But this isn't clean ice you could plink into a drink on a hot day. Like the ice found in permafrost here on Earth, this Martian ice is so thoroughly mixed up with dust and dirt that the only way to release its water would be to heat up the dirty material and melt it out.

There is deeper water too. While nuclear-powered rovers were busy photographing Mars's stunning landscapes and skies, NASA's solar-powered InSight lander's mission was to explore the interior structure of Mars using seismology.

Over four years its sensitive instruments recorded 'marsquakes' travelling through the planet, which suggested the existence of large reservoirs of liquid water deep within the Martian crust. However, at depths of 11.5 to 20 kilometres (7 to 12 miles), these reservoirs will not be easily accessible to future explorers and settlers.

Why is the existence of water on Mars, in any form, so important? Because it could be used not just to drink but to break down into hydrogen and oxygen, to make fuel and air, both of which will be essential resources for the establishment and survival of permanent bases on the Red Planet. And of course, wherever there is water on Earth we find life, so it's possible that primitive life might exist in these watery environments on Mars too.

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy and spaceflight

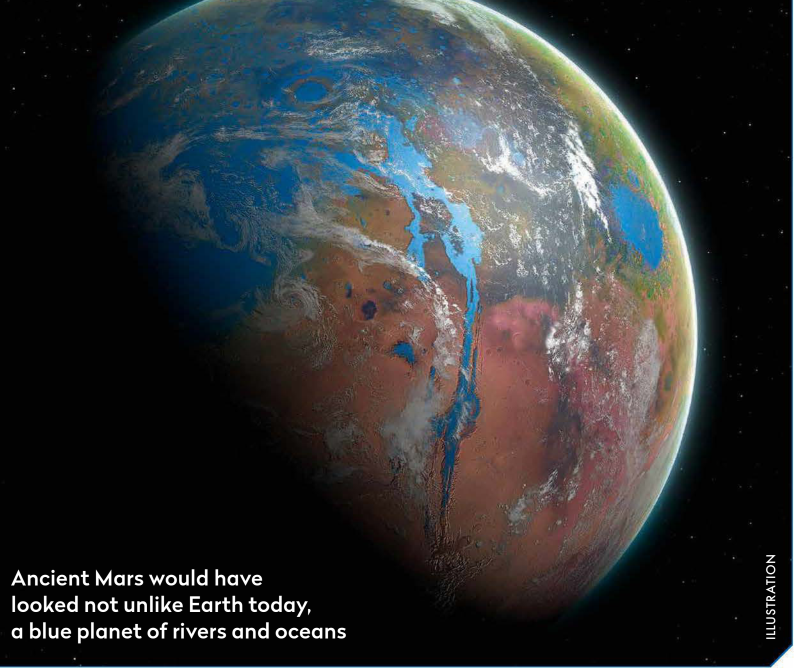
Where did the water go?

We can see Mars's wet history etched into its surface

While images from spacecraft in orbit around Mars show us that Mars is dry today, they also prove that it was much wetter in the past. These pictures showed meandering dried-up channels where water once flowed across the landscape, and even the shoreline of an ancient ocean that once covered much of the Red Planet's low, northern hemisphere. So if you jumped in a time machine and fell several billion years backwards through time, you'd probably see a very different Mars to the one we see today – a beautiful blue world much like our own, with rivers and streams flowing into a great northern ocean, all beneath a pale blue sky painted with fluffy white clouds.

So where did all this water go?

Over time, much of it was lost to space. Mars's weak magnetic field and low gravity allowed the solar wind to strip away its atmosphere, causing its water to slowly evaporate into space, leaving it dusty and dry. What Martian water remains today is either frozen into the ground or lies underground, having fallen through cracks in the surface rocks.



Ancient Mars would have looked not unlike Earth today, a blue planet of rivers and oceans

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16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

JANUARY 2025

LUNAR OCCULTATION OF SATURN

2025 gets off to a flying start with a rare lunar occultation of Saturn on 4 January

PETE LAWRENCE

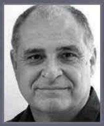
MEASURE THE GREAT RED SPOT

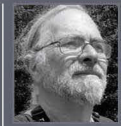
Take our challenge to size up Jupiter's giant storm

DAZZLING DOG STARS

Follow our tour of superb targets in Canis Major

About the writers


Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four


Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month…

- ✦ Favourable Quadrantid meteor shower peak
- ✦ Mars at opposition
- ✦ Titan shadow transits
- ✦ Minor planet 14 Irene at opposition in Gemini

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

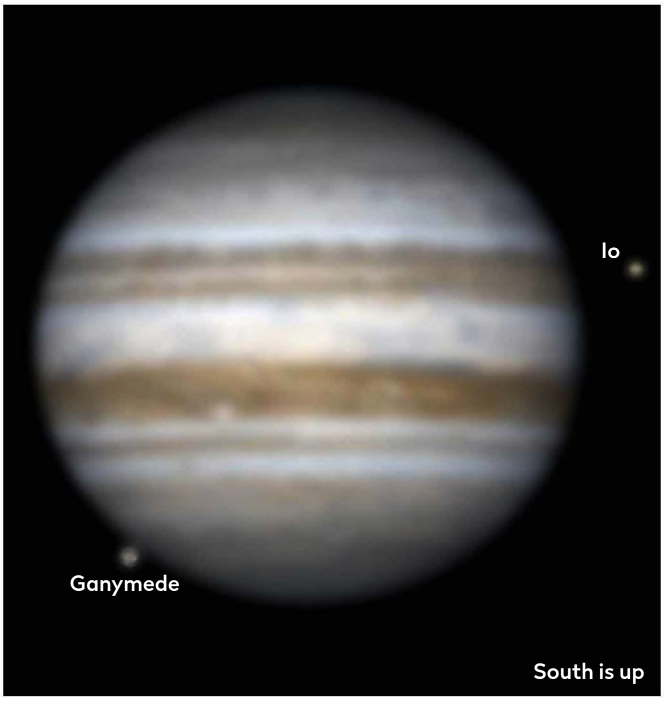
JANUARY HIGHLIGHTS

Your guide to the night sky this month

Thursday ▶

2

At 21:45 UT, Ganymede is occulted by Jupiter. Io transits as the occultation concludes, followed 38 minutes later by its shadow. Ganymede reappears at 23:52 UT and is eclipsed soon after by Jupiter's shadow at 00:19–02:50 UT on 3 January.



Friday

3

As evening twilight darkens, look for the beautiful sight of mag. –4.3 Venus just under 2° north-northwest of a 16%-lit waxing crescent Moon.

Quadrantid meteor shower peaks, with no real Moon interference.

Tuesday

7

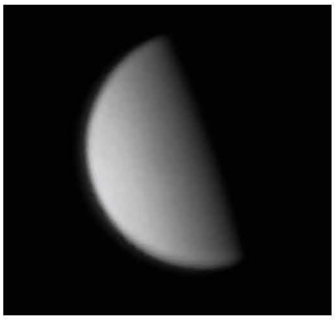
Titan's shadow transits Saturn's globe today, starting at 16:24 UT just after sunset and concluding at 21:32 UT.

The Eyes of Clavius lunar clair-obscur effect is visible at around midnight tonight.

Thursday ▶

9

In the run-up to midnight, the 81%-lit Moon can be seen approaching the Pleiades open cluster. The Moon will continue to pass across some of the brighter cluster stars in the early hours of 10 January.



◀ Friday

10

Magnificently bright planet Venus reaches greatest eastern elongation today, separated from the Sun by 47.2°. Dichotomy (50% phase) occurs on 12 January, after which Venus appears as a crescent through the eyepiece.

Monday

13

There's another opportunity to see a Ganymede shadow transit today. Ganymede itself transits Jupiter from 15:01 until 17:26 UT, its shadow following suit between 18:29 and 21:00 UT.

Tuesday

14

In the early hours, bright mag. –1.4 Mars sits about 10 arcminutes north of the full Moon's northern limb.

Moon Callisto sits 3 arcseconds from Jupiter's northern pole at 17:20 UT.

Thursday

23

Moon Callisto sits 3 arcseconds from Jupiter's southern pole this morning around 02:50 UT.

Titan casts its shadow on Saturn between 15:28 and 21:00 UT.

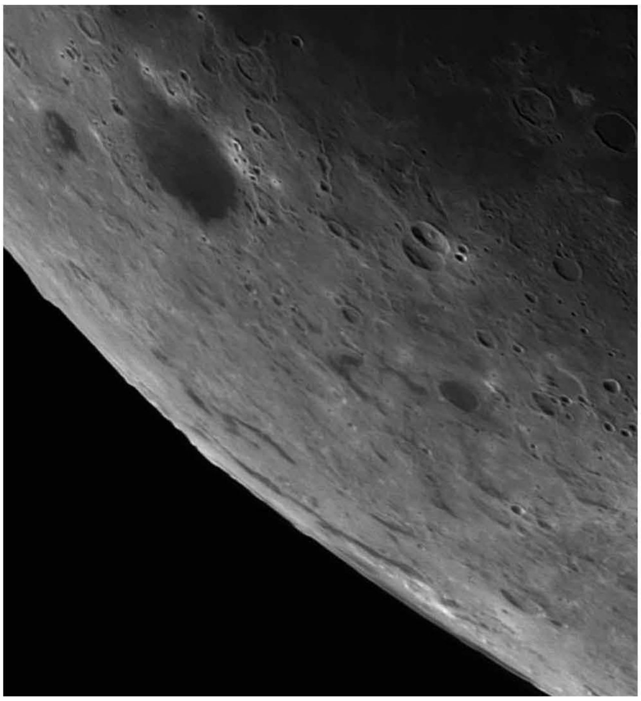
Saturday ▶

25

Lunar libration currently favours the Moon's western limb, giving the large Mare Orientale basin complex a slightly more favourable appearance.

Family stargazing

The planet Saturn is occulted (hidden) by the Moon in the early evening of 4 January, a great thing to engage young observers with. The waxing crescent Moon should be easy to find above the southern horizon after sunset, left and up a bit from brilliant Venus. Look out for Saturn just to the left of the Moon. Binoculars may help make the scene clearer. Make a point of recording the time of disappearance. Then, it's a matter of waiting for reappearance – binoculars or a small telescope are recommended for this. Turn to page 46 for full timing details. **www.bbc.co.uk/cbeebies/shows/stargazing**



PETE LAWRENCE X 6, ORIONS BELT: DAVIDHAJNAL/ISTOCK/GETTY

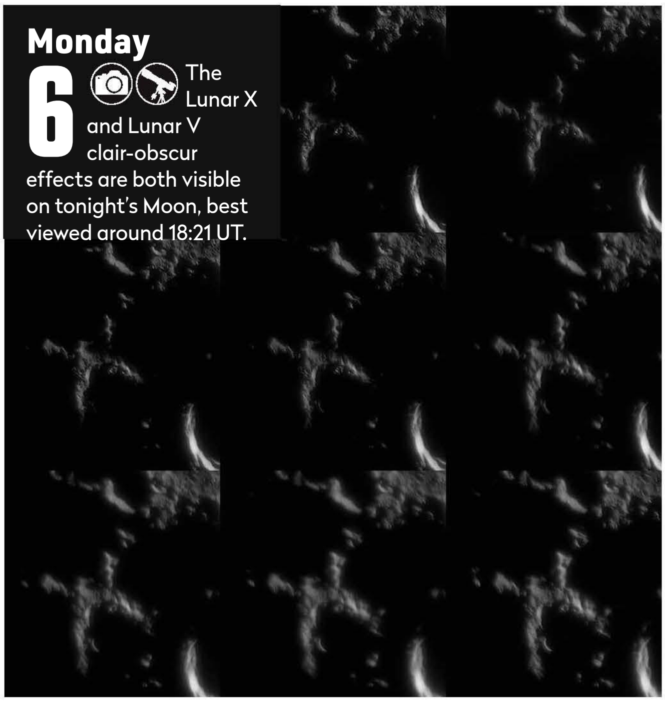
Saturday 4

Although it may not feel like it, Earth is at perihelion today, the point in its orbit when it's closest to the Sun.

Saturn is occulted by a 25%-lit waxing crescent Moon between 17:18 and 18:26 UT (see page 46).

Monday 6

The Lunar X and Lunar V clair-obscur effects are both visible on tonight's Moon, best viewed around 18:21 UT.



Thursday 16

Mag. –1.4 planet Mars reaches opposition today.

Saturday 18

Brilliant Venus sits just 2.2° to the north of dimmer Saturn this evening.

Monday 20

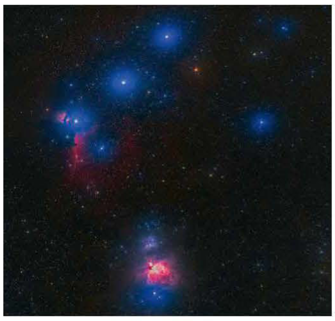
Ganymede puts on a display this evening, transiting the planet Jupiter between 18:32 and 20:58 UT. Its shadow follows later, transiting Jupiter's disc between 22:30 and 01:20 UT.

Monday 27

Ganymede puts on another transit event, crossing Jupiter between 22:07 and 00:34 UT. Its shadow follows, transiting from 02:31 until 05:04 UT. Jupiter will set at 04:36 UT, before the event concludes.

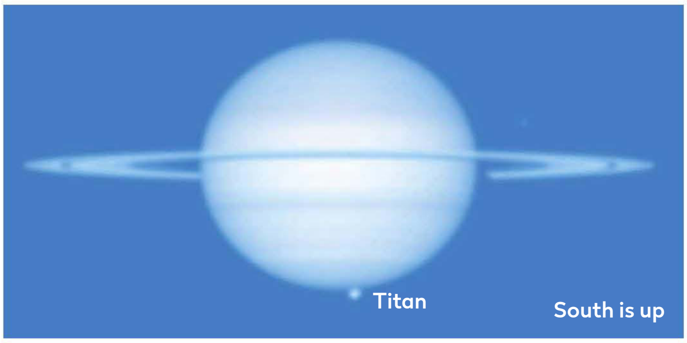
Tuesday 28 ▶

With the Moon now out of the way, this is a great time to look at the spectacular Sword of Orion region which contains the wonderful Orion Nebula, M42. The region is at its highest from around 21:15 UT.



Friday 31 ▶

Starting at 13:22 UT, there's a challenging daylight partial occultation of Titan by Saturn's northern limb. While partially occulted, Titan enters Saturn's shadow at 14:33 UT, reappearing at 19:43 UT while at low altitude.



NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly Objects marked with this icon are perfect for showing to children

Naked eye Allow 20 minutes for your eyes to become dark-adapted

Photo opp Use a CCD, planetary camera or standard DSLR

Binoculars 10x50 recommended

Small/ medium scope Reflector/SCT under 6 inches, refractor under 4 inches

Large scope Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

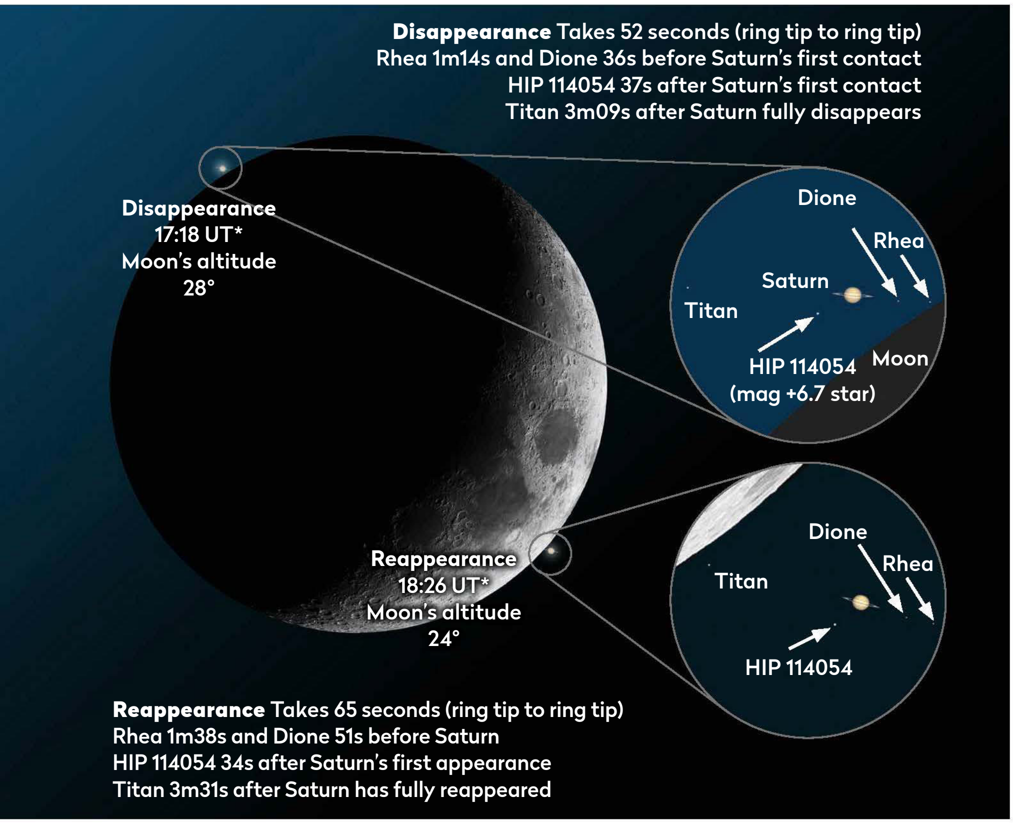
If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/stargazing-top-tips** to learn how to stargaze in 12 easy steps and **bit.ly/choose-first-telescope** for advice on choosing your first scope

THE BIG THREE The top sights to observe or image this month

DON'T MISS

Lunar occultation of Saturn

BEST TIME TO SEE: 4 January, 16:30–18:30 UT



Disappearance Takes 52 seconds (ring tip to ring tip)
Rhea 1m14s and Dione 36s before Saturn's first contact
HIP 114054 37s after Saturn's first contact
Titan 3m09s after Saturn fully disappears

Reappearance Takes 65 seconds (ring tip to ring tip)
Rhea 1m38s and Dione 51s before Saturn
HIP 114054 34s after Saturn's first appearance
Titan 3m31s after Saturn has fully reappeared

◀ See Saturn vanish behind the Moon on 4 January, reappearing 68 minutes later

*Times shown are for the centre of the UK and will vary with location

Lunar occultations of planets are fairly infrequent affairs. The last lunar occultation of Saturn occurred on 21 August 2024, although you'd need to go back to 2007 for one before that which was visible from the UK.

While August's event involved a 97%-lit waning gibbous Moon moving in front of Saturn in the brightening dawn twilight, the transit on 4 January occurs in the early evening sky, the occulting Moon being a 25%-lit waxing crescent.

Saturn's disappearance occurs under darkening skies after sunset. The Moon should be easy to spot around 16:30 UT, one-third of the way up the sky, just west of south. It'll also be 12.5° east-northeast of brilliant mag. –4.3 Venus at this time. Saturn will be a lot dimmer than Venus at mag. +0.8, only becoming visible just left of the Moon as the sky darkens.

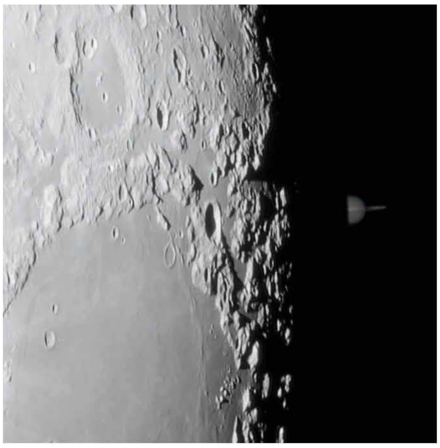
Hopefully, the event will be assisted by the presence of strong earthshine, the effect that makes the night side of the Moon glow slightly. It's caused by light from the Sun reflecting off Earth, hitting the Moon's night surface and reflecting back to Earth. If it is visible, it'll give you an excellent indication as to where and when occultation disappearance will occur. If not, you'll need to 'round the circle' using your imagination and the visible part of the lunar crescent.

Occultation disappearance occurs at 17:18 UT, a time correct for the centre of the UK, but one which may vary by a few minutes depending on your location in the country. The Moon is close enough to exhibit parallax, where its position shifts slightly from different locations, affecting the timings slightly.

Disappearance behind the Moon's dark edge takes 52 seconds. Interestingly, HIP 114054, a mag. +6.7 star, will be located 36 arcseconds southeast of Saturn's centre and undergoes occultation disappearance at the same time as the planet. You should be able to see Saturn's largest and brightest moon, Titan, undergoing occultation disappearance 3 minutes 9 seconds after Saturn.

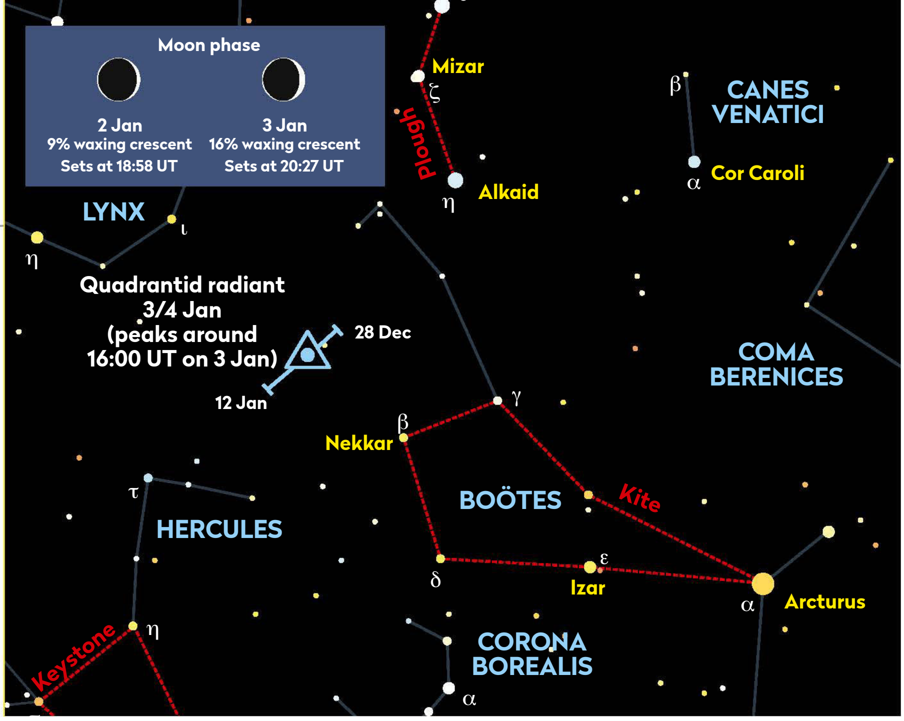
Reappearance begins around 18:26 UT (centre of the UK time), with the western section of Saturn's rings appearing ahead of the planet's globe. This was a particularly striking thing to see during the August 2024 occultation and should be equally as dramatic for this month's event.

Saturn will take 65 seconds to fully reappear. Don't forget to look out for HIP 114054 reappearing along with Saturn. Titan reappears from behind the Moon's bright limb 3 minutes 31 seconds after Saturn, bringing the event to a close. Occultation reappearance occurs under darker sky conditions, with Saturn 23° up above the southwest horizon.



▲ Saturn emerged ring-first from the Moon's dark limb last August. This month, it'll appear from the Moon's bright limb

ALL PICTURES: PETE LAWRENCE



▲ This year's Quadrantid peak will appear under favourable Moon conditions

Quadrantids 2025

BEST TIME TO SEE: Evening of 3 January, from when it gets dark

The Quadrantid meteor shower is active from 28 December to 12 January, with low activity over most of this period. It swings into high activity over a period of just a few hours, this year centred on 16:00 UT on 3 January. It can produce a maximum zenithal hourly rate (ZHR) of around 120 meteors per hour.

The shower radiant – that's the point in the sky from which the shower meteors appear to emanate – will be very low around 16:00 UT on 3 January, so a watch through the whole night is recommended for the best views, the radiant gaining altitude as you go towards dawn.

The shower gets its name from the now-defunct constellation of Quadrans Muralis, the Mural Quadrant. The radiant position is located in northern Boötes bounded by Ursa Major, Draco and Hercules. Visualise its position by extending the straight portion of the Plough's handle through Megrez–Alioth–Mizar (Delta (δ)–Epsilon (ε)–Zeta (ζ) Ursae Majoris) for 1.5x that distance again.

The cold, post-holiday season period can be uninviting, but it's worth being tenacious, putting the thermals on and braving the cold, because this is a very decent shower to observe. A sunlounger is the best platform to use, but do wrap up warm and plan several breaks. As ever, make sure you're in as dark an area as possible and give your eyes at least 20 minutes in total darkness before starting.

Looking in any direction will do, but meteor wisdom suggests looking at an altitude two-thirds up the sky where the atmosphere is sufficiently thin to not block too much light from meteor trails, but thick enough to provide enough atmosphere for meteors to appear within.

Venus and Saturn

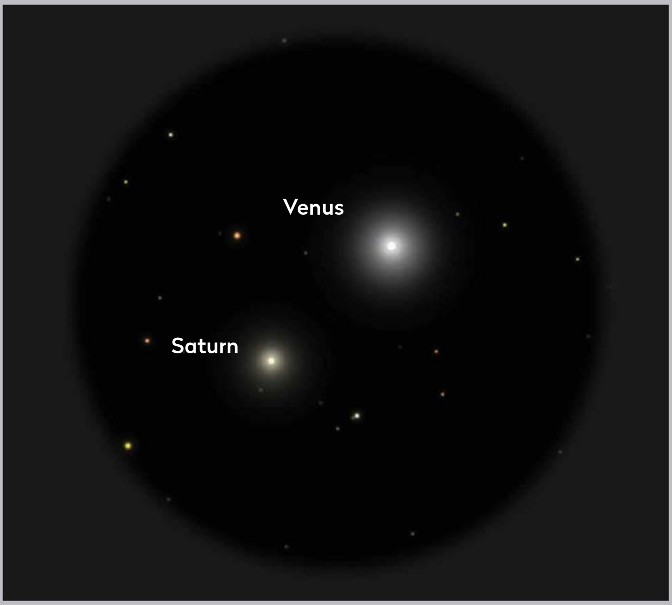
BEST TIME TO SEE: 10–25 January, smallest separation on 18 January

Venus and Saturn have a meet-up this month, an event that is conveniently timed for early evening viewing in the darkening sky after sunset. Venus is currently pretty bright at mag. –4.3; located above the southwest horizon early evening, it's difficult to miss. Saturn is dimmer at mag. +0.8, located 16° to the east-northeast of Venus on 1 January.

Venus is joined by a 16%-lit waxing crescent Moon on the evening of 3 January, the planet located just under 2° north-northwest of the Moon on this date. On the following evening, now at 25%-illumination, the Moon will occult Saturn (see page 46).

On 10 January, Venus appears 47.2° from the Sun, having reached a position known as greatest eastern elongation. Basically, the angle between the lines formed by joining Earth to Venus and Venus to the Sun will be a right angle on this date. If you've been paying attention and have had clear weather in early January, you'll notice that Venus appears closer to Saturn on 10 January, separated by just 7.5°.

This separation continues to decrease until 18 January, when both planets will be just 2.2° apart (you could fit four full Moons between them). Venus then separates from the ringed planet once more.



▲ How Venus and Saturn will appear through 7x50 binoculars on the evening of 18 January, when the pair will be just 2.2° apart

THE PLANETS Our celestial neighbourhood in January

PICK OF THE MONTH

Mars

Best time to see: 12 January, 00:48 UT
Altitude: 62°
Location: Gemini
Direction: South
Features: Polar caps, surface markings, weather
Recommended equipment: 75mm scope or larger

Mars reaches opposition on 16 January 2025, the moment when the planet sits on the opposite side of the sky to the Sun – technically, separated from the Sun by 180° of ecliptic longitude. At opposition, the distance between a superior planet (those with larger orbits than Earth's) and planet Earth is minimised for the current period of observation. This leads to the opposition planet appearing at its largest and brightest for that period.

There are a couple of caveats with this year's Mars opposition. Firstly, the distance between Earth and Mars is actually at its minimal value on 12 January, four days before technical opposition. Also, this opposition is regarded as aphelic, meaning Mars is in a position where it is nearer to the furthest point of its orbit around the Sun and hence more distant from Earth.

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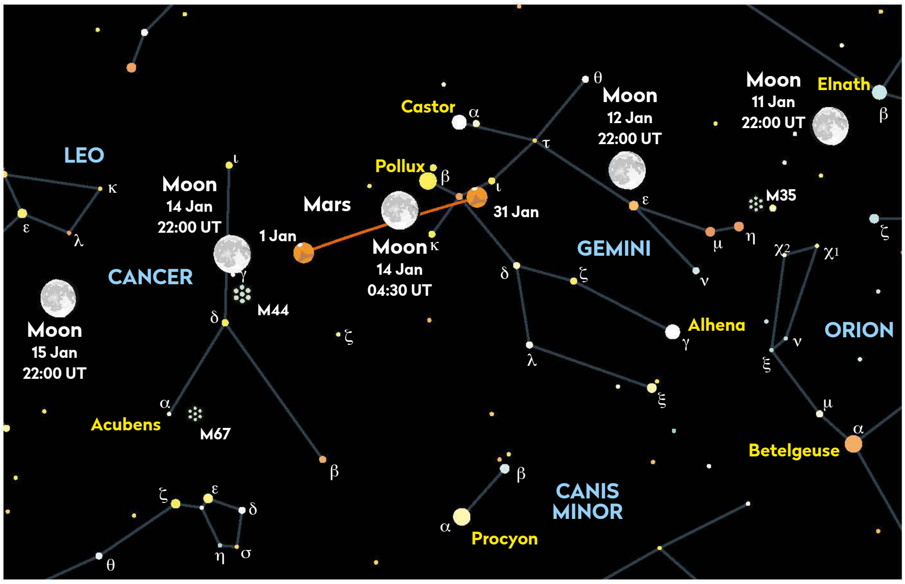
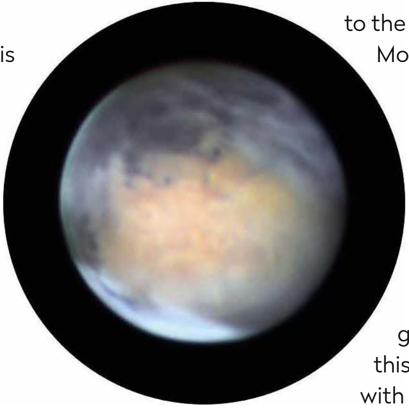

LEO
CANCER
GEMINI
ORION
CANIS MINOR
Castor
Pollux
Elnath
Alhena
Betelgeuse
Procyon
Acubens
M44
M67
M35
Mars
1 Jan
31 Jan
Moon 11 Jan 22:00 UT
Moon 12 Jan 22:00 UT
Moon 14 Jan 22:00 UT
Moon 14 Jan 04:30 UT
Moon 15 Jan 22:00 UT

▲ Big, bright Mars moves into Gemini this month, remaining nice and high for observation

The bad news here is that Mars will only reach an apparent diameter of 14.6 arcseconds this month. The good news is that it does so at a very favourable position in the sky, high in the constellation of Gemini and able to reach 62° altitude under dark sky conditions.

Mars appears bright, shining at mag. –1.2 on 1 January. It moves from Cancer into Gemini throughout the month in a westerly (retrograde) direction. On 14 January at 04:30 UT, the Red Planet sits 26 arcminutes to the north of the full Moon's centre.

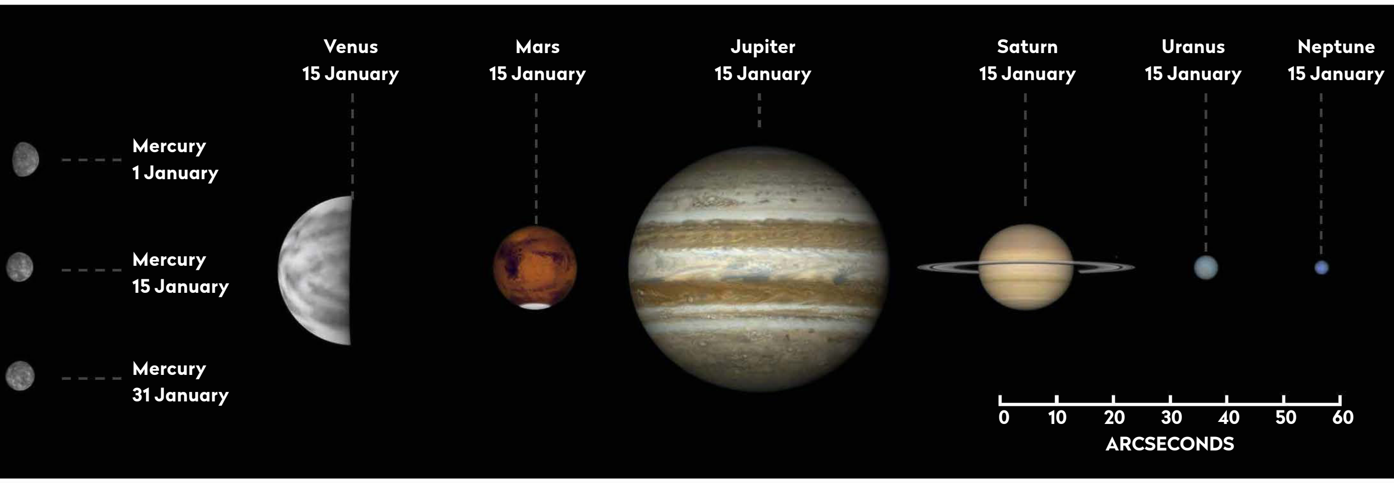
By the end of the month, Mars will shine at mag. –1.1 and will have an apparent diameter of 13.8 arcseconds, reaching a peak altitude of 63°. January 2025 is a great time to observe this interesting planet with a telescope, recording its dark surface markings, polar caps, weather and occasional dust storms.

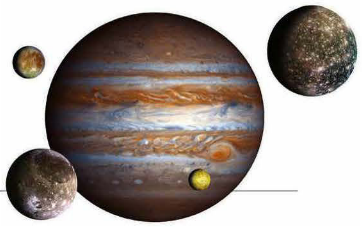


▲ Mars comes to opposition – a great time to observe its features

The planets in January

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope


Venus 15 January
Mars 15 January
Jupiter 15 January
Saturn 15 January
Uranus 15 January
Neptune 15 January
Mercury 1 January
Mercury 15 January
Mercury 31 January
0
10
20
30
40
50
60
ARCSECONDS



Mercury

Best time to see: 1 January, from 40 minutes before sunrise
Altitude: 4° (very low)
Location: Ophiuchus
Direction: Southeast

Morning planet that's best at the start of January low in the dawn twilight. Shining at mag. –0.3, Mercury is visible 40 minutes before sunrise, but not optimally. It's lost from view around 9 January as it heads back towards the Sun.

Venus

Best time to see: 10 January, 1 hour after sunset
Altitude: 24°
Location: Aquarius
Direction: South-southwest

Brilliant evening planet, best from 1 hour after sunset at the start of the month. Greatest eastern elongation on 10 January, separated from the Sun by 47.2° and setting 4.5 hours after sunset. On the evening of 3 January, a 16%-lit waxing crescent Moon sits 2° south of Venus. On 18 January, mag. –4.4 Venus sits 2.2° north-northwest of mag. +0.8 Saturn. After greatest eastern elongation, it changes quite rapidly through the eyepiece. On 12 January, its phase is 50%, but by 31 January this decreases to 38%, its apparent diameter increasing from 25 arcseconds to 31 arcseconds.

Jupiter

Best time to see: 1 January, 22:10 UT
Altitude: 59°
Location: Taurus
Direction: South

A resplendent evening object shining at mag. –2.6. It passed opposition at the start of last month and is best at the start of January, reaching 59° when due south under darkness. An 89%-lit waxing gibbous Moon sits 5° north of Jupiter on 10 January. By the end of the month, the planet shrinks to appear 43 arcseconds across, 3 arcseconds smaller than on 1 January.

Saturn

Best time to see: 1 January, 17:30 UT
Altitude: 27°
Location: Aquarius
Direction: South-southwest

Unable to reach peak altitude under darkness, it remains well placed for observation at the start of January. Occulted by a 25%-lit waxing crescent Moon on 4 January (see page 46). On 18 January, shining at mag. +0.8, Saturn sits 2.2° south-southeast of mag. –4.4 Venus in deep twilight.

Uranus

Best time to see: 1 January, 20:45 UT
Altitude: 55°
Location: Aries
Direction: South

Relatively near Jupiter and well placed. Shining at mag. +5.7, it reaches 55° when due south. Currently in Aries, virtually on the border with Taurus.

Neptune

Best time to see: 1 January, 18:10 UT
Altitude: 34°
Location: Pisces
Direction: South-southwest

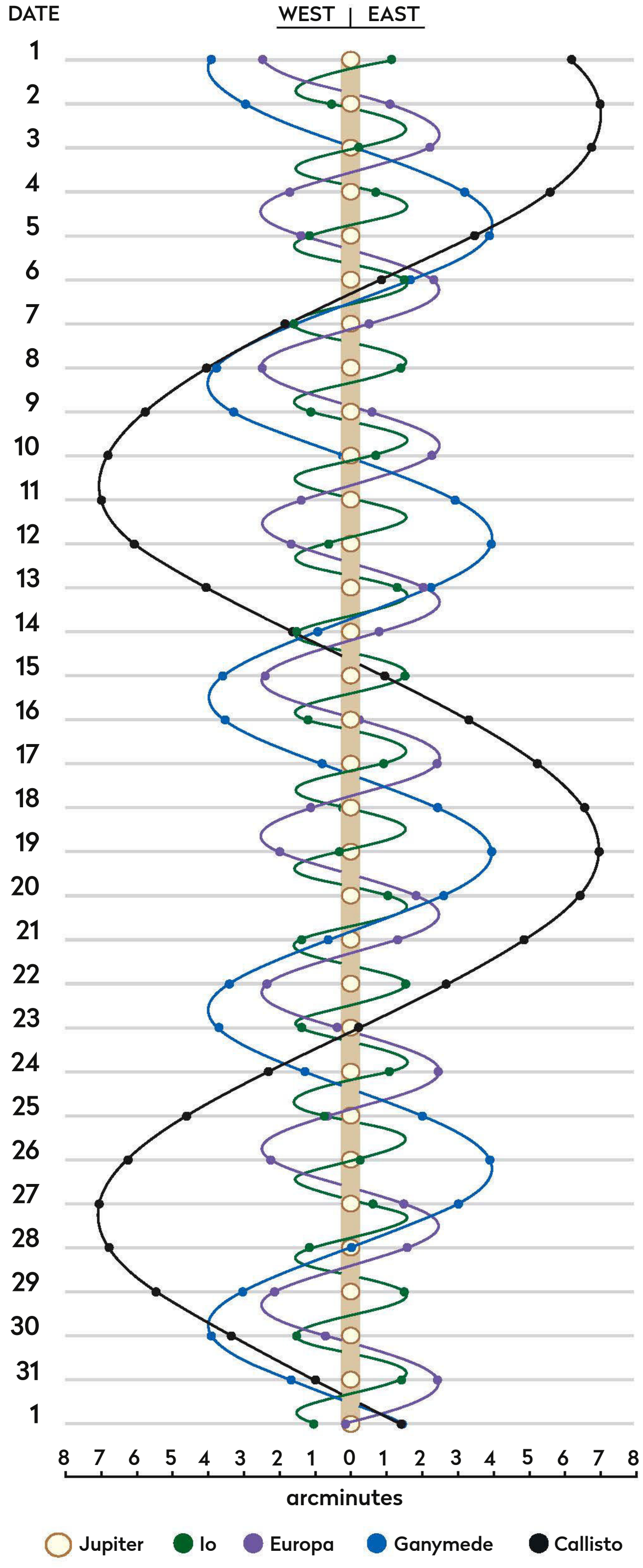
Mag. +7.9 evening planet in Pisces. Best seen at the start of January, it loses altitude as darkness falls at the end of the month. Neptune is occulted by a 34%-lit crescent Moon at 13:54–14:54 UT on 5 January but won't be visible in daylight. At 19:00 UT on 31 January, Neptune is separated from Venus by 3.2°.

FREE BONUS CONTENT

Print planet observing forms www.skyatnightmagazine.com/bonus-content

JUPITER'S MOONS: JANUARY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – JANUARY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
⬭	GALAXY
◌ ⁘	OPEN CLUSTER
⊕	GLOBULAR CLUSTER
☼	PLANETARY NEBULA
□	DIFFUSE NEBULOSITY
●	DOUBLE STAR
○	VARIABLE STAR
◐	THE MOON, SHOWING PHASE
☄	COMET TRACK
●	ASTEROID TRACK
┈	STAR-HOPPING PATH
△	METEOR RADIANT
Circlet	ASTERISM
🪐	PLANET
☼	QUASAR

STAR BRIGHTNESS:

●	MAG. 0 & BRIGHTER
●	MAG. +1
•	MAG. +2
•	MAG. +3
·	MAG. +4 & FAINTER
5° N E W S	COMPASS AND FIELD OF VIEW
	MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

1 January at 00:00 UT

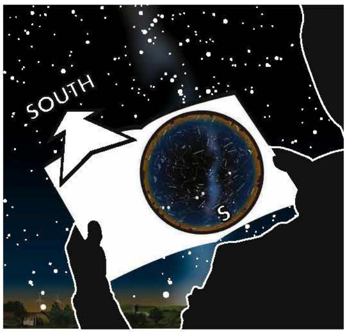
15 January at 23:00 UT

31 January at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.



Sunrise/sunset in January*

Date	Sunrise	Sunset
1 Jan 2025	08:25 UT	16:01 UT
11 Jan 2025	08:21 UT	16:15 UT
21 Jan 2025	08:10 UT	16:32 UT
31 Jan 2025	07:56 UT	16:51 UT

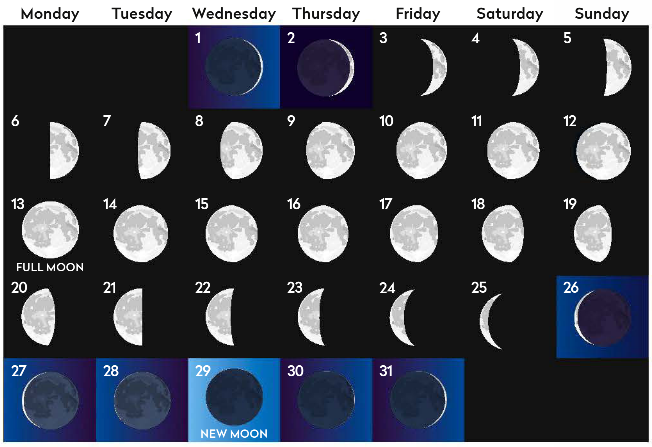
Moonrise in January*

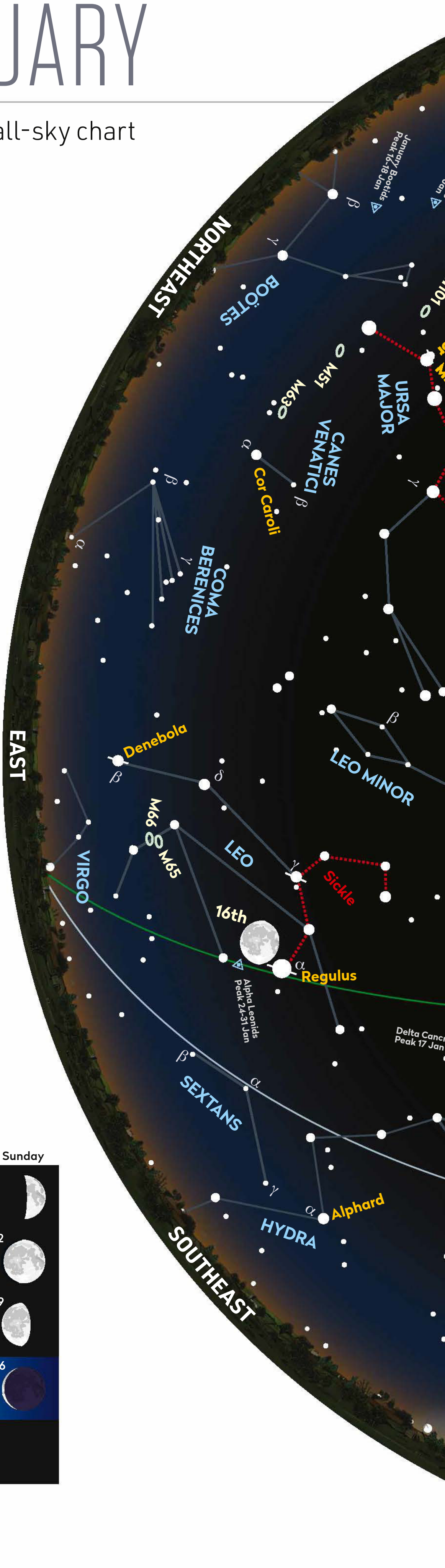
Moonrise times

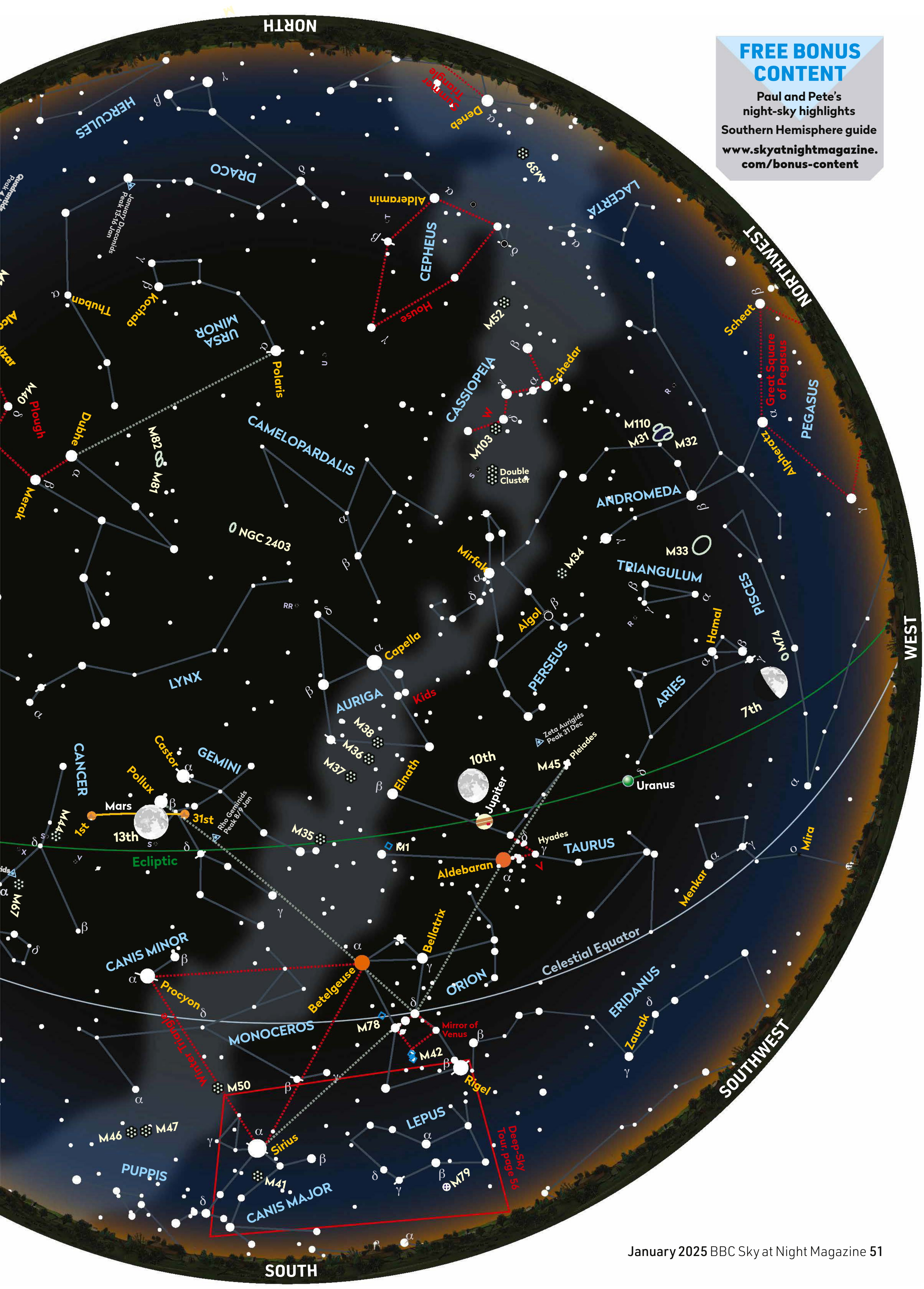
1 Jan 2025, 10:09 UT	17 Jan 2025, 20:45 UT
5 Jan 2025, 11:05 UT	21 Jan 2025, 00:25 UT
9 Jan 2025, 11:56 UT	25 Jan 2025, 05:30 UT
13 Jan 2025, 15:17 UT	29 Jan 2025, 08:33 UT

*Times correct for the centre of the UK

Lunar phases in January


Monday
Tuesday
Wednesday
Thursday
Friday
Saturday
Sunday
1
2
3
4
5
6
7
8
9
10
11
12
13
FULL MOON
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
NEW MOON
30
31


January Bootids
Peak 16-18 Jan
NORTHEAST
BOÖTES
M51
M63
URSA MAJOR
CANES VENATICI
Cor Caroli
COMA BERENICES
Denebola
EAST
LEO MINOR
M66
M65
LEO
Sickle
VIRGO
16th
Regulus
Alpha Leonids
Peak 24-31 Jan
Delta Canc
Peak 17 Jan
SEXTANS
HYDRA
Alphard
SOUTHEAST


NORTH
HERCULES
DRACO
Quadrantids Peak 4
January Draconids Peak 13-16 Jan
Thuban
Kochab
URSA MINOR
Polaris
Deneb
Summer Triangle
M39
Alderamin
CEPHEUS
House
LACERTA
NORTHWEST
Scheat
Great Square of Pegasus
PEGASUS
Alpheratz
M52
Schedar
CASSIOPEIA
W
M103
Double Cluster
M110
M31
M32
ANDROMEDA
M33
TRIANGULUM
PISCES
M74
Hamal
ARIES
7th
WEST
Mizar
Alcor
M40
Plough
Dubhe
Merak
M82
M81
CAMELOPARDALIS
NGC 2403
Mirfak
M34
Algol
PERSEUS
Zeta Aurigids Peak 31 Dec
Pleiades
M45
Uranus
Capella
LYNX
AURIGA
Kids
M38
M36
M37
Elnath
10th
Jupiter
CANCER
Castor
GEMINI
Pollux
Mars
1st
13th
31st
Rho Geminids Peak 8/9 Jan
M44
M35
M1
Hyades
TAURUS
Aldebaran
Ecliptic
M67
Menkar
Mira
Bellatrix
Celestial Equator
CANIS MINOR
Procyon
Betelgeuse
ORION
ERIDANUS
MONOCEROS
M78
Mirror of Venus
M42
Rigel
Zaurak
SOUTHWEST
Winter Triangle
M50
LEPUS
M46
M47
PUPPIS
Sirius
M41
M79
CANIS MAJOR
Deep-Sky Tour, page 56
SOUTH

FREE BONUS CONTENT

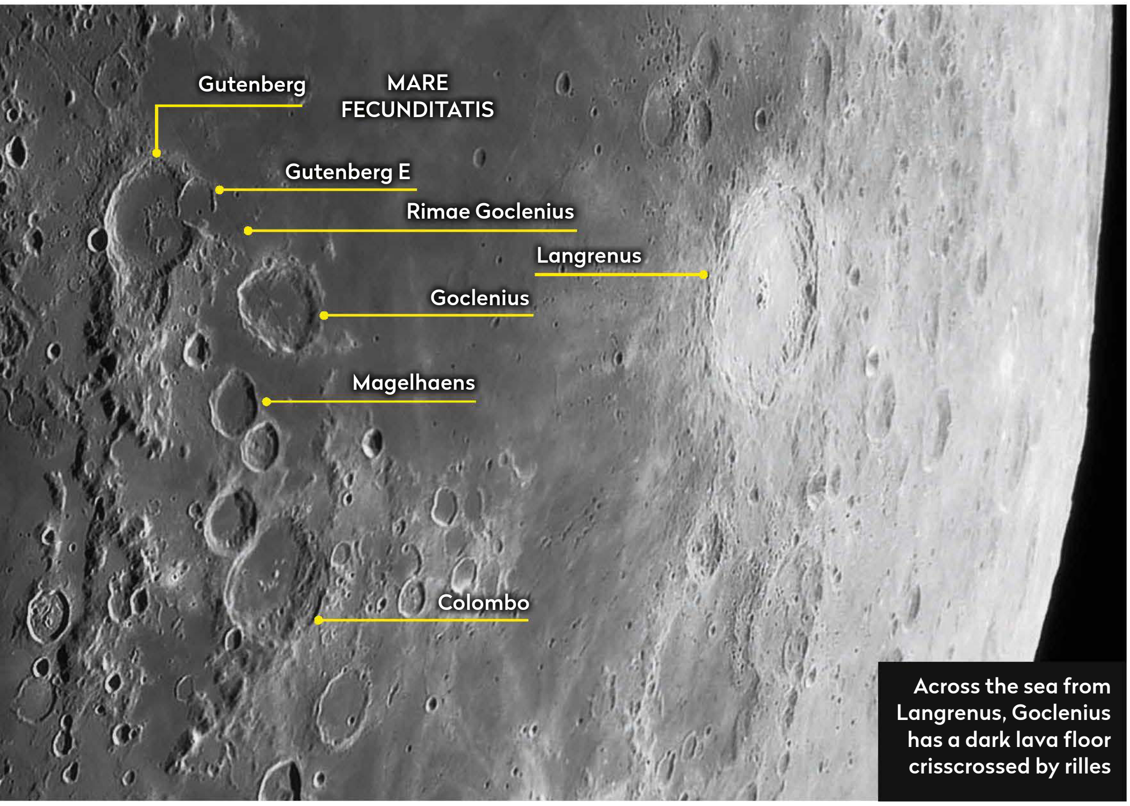
Paul and Pete's night-sky highlights

Southern Hemisphere guide

www.skyatnightmagazine.com/bonus-content

MOONWATCH

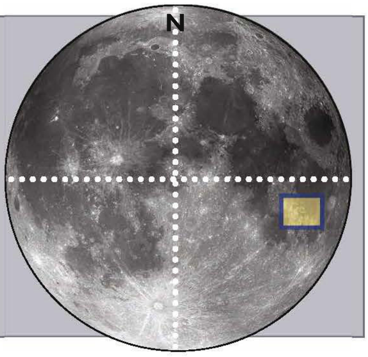
January's top lunar feature to observe



Across the sea from Langrenus, Goclenius has a dark lava floor crisscrossed by rilles

Goclenius

Type: Crater
Size: 55km
Longitude/latitude: 45° E, 10.1° S
Age: Around 3.9 billion years
Best time to see: Four days after new Moon (3 January and 1 February) or three days after full Moon (17–18 January)
Minimum equipment: 50mm telescope



Goclenius is a 55km crater located within the 600 x 500km Sea of Fertility, **Mare Fecunditatis**. The irregularly shaped mare resembles the shape of a diamond, with the distinctive form of 133km **Langrenus** on the southeast straight edge and Goclenius in a similar position on the southwest straight.

Goclenius is an ancient crater, the floor of which has been flooded by lava. It sits within a region of similar company: 75km **Gutenberg** to the northwest, 41km **Magelhaens** to the southwest and 76km **Colombo** to the south. All of them and many of their labelled satellites have lava-filled floors.

There's some exquisitely fine detail here. The remaining ring surrounding Goclenius's flat floor is more or less continuous with a few gently smoothed terraces. It loses some cohesion towards the north, although never fully opens to the surrounding mare. Compare it with the wonderful form of Gutenberg, which has a well-defined rim all the way around except at the east where it has been completely overlaid by 28km **Gutenberg E,** which has removed any trace of the original Gutenberg rim section. Gutenberg E is itself open, with rim gaps in the southwest and southeast. Together, these create an open path to the flat lava surface of Mare Fecunditatis to the east, both Gutenberg and Gutenberg E being flooded.

Back to Goclenius, and the crater's rim also appears to have a pinch-point to the south. This seems to be a continuous portion of the rim, but at certain illuminations is exaggerated into looking as if there's a gap. Goclenius is around 2km deep, its flat lava floor covered in shallow hills and a beautifully delicate crisscrossing rille system. Many of these rilles are too fine for all but the largest scopes or high-resolution setups, but even with those will require decent seeing to reveal well.

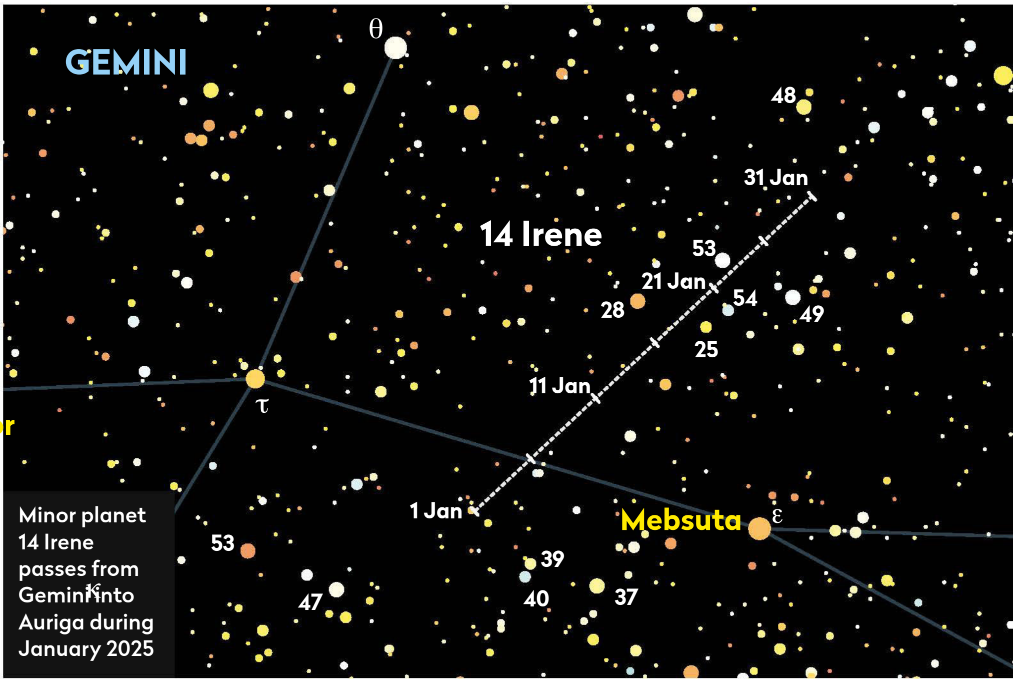
One notable exception is the largest rille that runs northwest to southeast. This has a width of just over 1km and appears to pass through Goclienius's closest approximation to a central mountain complex – although, with a height of around 350–400m, 'mountain' is stretching the description. The rille passes up through the northwest rim section, delicately depressing the rim as it does so. It then continues across the western floor of Mare Fecunditatis, clipping the eastern side of Gutenberg E, before continuing on its way and petering out just east of 31km **Gutenberg G**. This rille is part of the **Rimae Goclenius** complex, other less obvious members running parallel to the most prominent one described, slightly east of it up the floor of Mare Fecunditatis.

A wonderful part of the Moon to explore when the Sun is low

As ever, these rilles are best seen when the region lighting is oblique – in other words, when the lunar terminator is nearby. Unlike its immediate neighbours, Goclenius looks to be separated from the shores of Mare Fecunditatis, appearing almost framed by a continuous region of surrounding flat mare lava. A few local elevations appear around it, notably to the northeast and southeast, all adding to a wonderful part of the Moon to explore when the Sun is low in its sky.

COMETS AND ASTEROIDS

Track 14 Irene as it reaches opposition in Gemini



Minor planet 14 Irene passes from Gemini into Auriga during January 2025

Minor planet 14 Irene reaches opposition on 2 January when it can be found shining against the stars of Gemini at magnitude +9.5. By the end of the month, it fades slightly to mag. +10.1, making it an ideal target to track down if you have a small or larger telescope.

Irene starts January a little to the east of the mid-point between the two stars that form the 'body' of the stick figure of the twin Castor: mag. +4.4 Tau (τ) Geminorum and +3.1 Mebsuta (Epsilon (ε) Geminorum). Thereafter, it tracks in a linear fashion west-northwest to end the month within the southeast boundary of Auriga. In total, the full track length is a little over 7°, making Irene fairly easy to keep track of once you've located it.

As ever with objects of this type, all you'll see will be a star-like point disguised against the more distant star field background. In order to identify that you have genuinely observed the body, it's necessary to record the suspected field over the course of several nights, making note of any objects that appear to move through it.

Irene is a large main-belt asteroid that orbits the Sun at a mean distance of 2.565 AU. Its mean diameter is 152km and it rotates once on its axis in 15 hours.

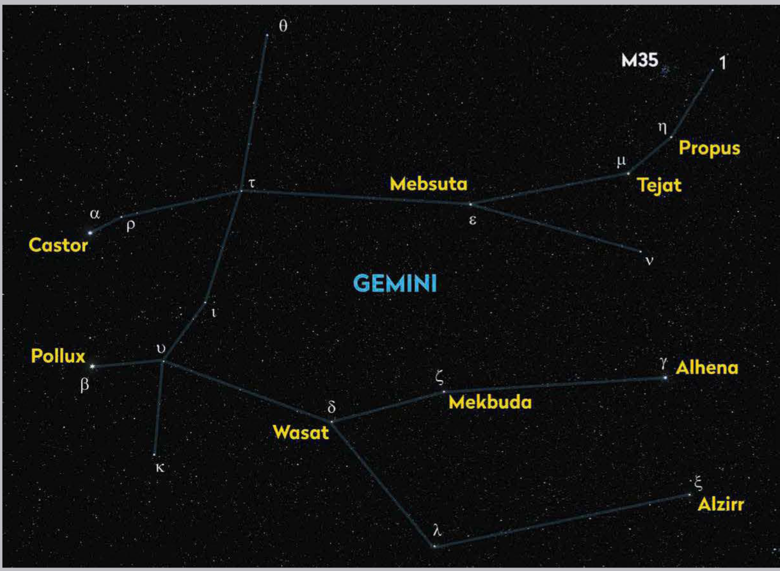
STAR OF THE MONTH

Mebsuta, a yellow supergiant in Gemini

Mebsuta (Epsilon (ε) Geminorum) is a mag. +3.0 star in Gemini, part of the northern twin Castor. You'd be forgiven for assuming its name translates to something to do with the twins, but it actually means 'outstretched paw'. Equally as curious, 6.5° southeast of Mebsuta lies Mekbuda (Zeta (ζ) Geminorum), the name of which means 'the lion's folded paw'. As you might now guess, the names relate to a lion, this being a pattern recognised in ancient Arabic stories.

Mebsuta has a spectral classification of G8 Ib, which means it's a yellow supergiant and its spectrum is used as a reference against which other stars are compared. With a mass 5.3 times that of the Sun, Mebsuta's radius has been measured directly by the Navy Precision Optical Interferometer at the Anderson Mesa Station of the Lowell Observatory in Arizona. This allowed the star's size to be determined as 130 times larger than the Sun. As Mebsuta sits just under 2° from the ecliptic, it's a candidate for lunar occultations. When this happens, high-resolution analysis can also be used to determine the star's size.

Mebsuta is a cool G star, with a temperature around 4,600K. Compare this with the Sun, another G-type star, which has a photospheric surface temperature of 5,772K. Despite this, Mebsuta's large size leads to an overall luminosity which is just shy of 7,000 times that of the Sun.

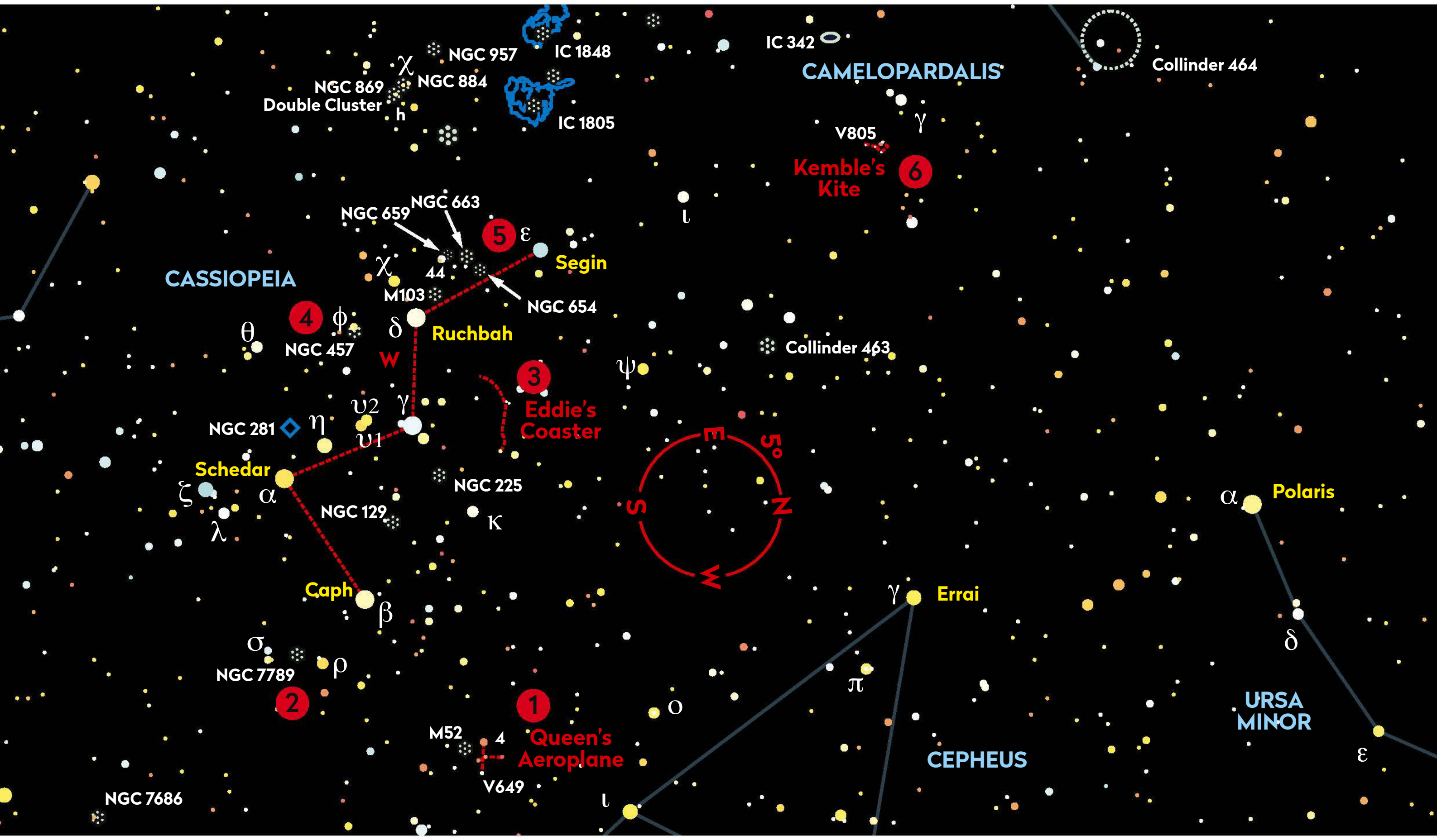


▼ Located 860 lightyears away, Mebsuta marks the point where the stick-figure Castor's legs join his body

BINOCULAR TOUR

With Steve Tonkin

Ride a coaster, fly a kite, catch a plane – and don't forget to stop and smell the rose


NGC 957
IC 1848
IC 342
CAMELOPARDALIS
Collinder 464
NGC 869
Double Cluster
χ
h
NGC 884
IC 1805
V805
γ
Kemble's Kite
6
ι
NGC 659
NGC 663
5
ε
Segin
CASSIOPEIA
χ
44
M103
NGC 654
4
φ
θ
NGC 457
δ
Ruchbah
W
3
Eddie's Coaster
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Collinder 463
NGC 281
η
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NGC 225
κ
α
Polaris
Caph
β
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Errai
δ
σ
NGC 7789
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π
1
Queen's Aeroplane
M52
4
V649
o
URSA MINOR
CEPHEUS
ε
NGC 7686
ι

1. The Queen's Aeroplane

10x50 Locate golden-yellow mag. +5.0 4 Cassiopeiae, which marks the starboard wingtip of this little aeroplane-shaped asterism (pattern of stars). The other wingtip, a degree to the west, is the mag. +6.6 blue-white V649 Cassiopeiae. The curved 'fuselage' of stars that shine at mag. +8.0 or brighter extends a degree northwards to a mag. +6.7 orange-red star. There's a lovely variety of star colours here, which a dark transparent sky will help you to appreciate. ☐ **SEEN IT**

2. Caroline's Rose, NGC 7789

10x50 Caroline Herschel discovered our next target in 1783. You'll find it between mag. +4.5 Rho (ρ) and mag. +5.1 Sigma (σ) Cassiopeiae. You won't be able to resolve any stars, even using averted vision, but you should see a soft glow about half the apparent diameter of the Moon. Caroline's Rose is estimated to be about a billion years old, which is unusually old for an open cluster. ☐ **SEEN IT**

3. Eddie's Coaster

10x50 This asterism was discovered by, and is named after, the West Country amateur astronomer Eddie Carpenter. Given that it's difficult to identify on a star chart or app, Eddie's Coaster is surprisingly obvious in 10x50 binoculars. Look 3° north of Gamma (γ) Cassiopeiae to find a 3°-long wave of seventh and eighth-magnitude stars, reminiscent of a rollercoaster. Cast around the area; you too may find a pattern of interest. ☐ **SEEN IT**

4. The Owl Cluster, NGC 457

10x50 Start at mag. +2.6 Ruchbah (Delta (δ) Cassiopeiae) and navigate 2° southwest to mag. +5.0 (Phi (φ) Cassiopeiae) and its mag. +7.0 companion 2 arcminutes further on. These are the owl's eyes. Its body and wings are composed of ninth and 10th-magnitude stars that span an area about 0.25° in the direction of γ Cassiopeiae. The owl's brighter eye is not a cluster member, lying only half as far away. ☐ **SEEN IT**

5. Cassiopeia triple cluster: NGC 654, NGC 659 and NGC 663

15x70 Look 0.5° east of the middle of an imaginary line joining Ruchbah and mag. +3.3 Segin (Epsilon (ε) Cassiopeiae) and you'll easily find the brightest of these clusters, NGC 654. Slightly less than 1° to the south-southeast is the larger but fainter NGC 663. Your challenge is to spot the tiny ghostly glow of NGC 659, just on the NGC 663 side of the mag. +5.8 44 Cassiopeiae. ☐ **SEEN IT**

6. Kemble's Kite

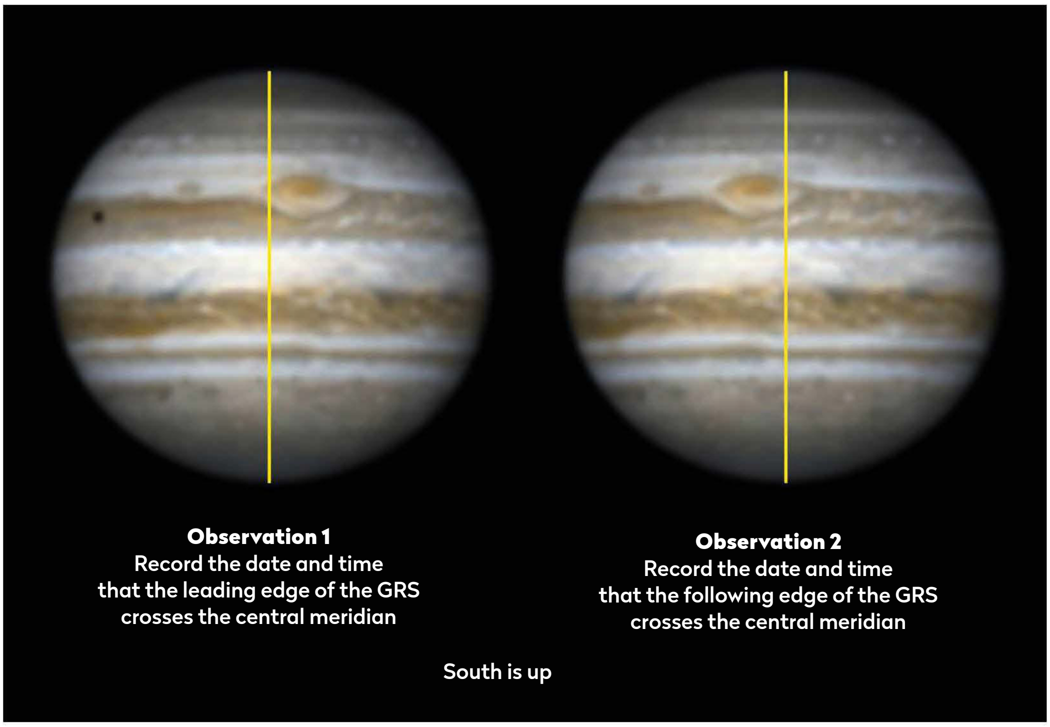
15x70 From Segin, take a line through mag. +4.6 Iota (ι) Cassiopeiae and extend it 7° to mag. +6.4 V805 Cassiopeiae, which will look deep yellow in binoculars. It's the brightest of a 1.5°-long asterism of 10 mag. +8.5 and brighter stars forming a diamond kite with a tail that flows south towards Perseus. There's an easily splittable double star at the kite's northern tip. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Jupiter's Great Red Spot seems to be shrinking. Can you measure its size for yourself?



Observation 1
Record the date and time
that the leading edge of the GRS
crosses the central meridian

Observation 2
Record the date and time
that the following edge of the GRS
crosses the central meridian

South is up

▲ **Our challenge is to measure the width of the Solar System's biggest storm, the Great Red Spot, by recording the moment when its leading edge and then its following edge cross Jupiter's central meridian**

A great deal of emphasis is put on astronomical imaging these days, and the science of astronomy sometimes gets left behind as a result. However, one important area of observation, measurement and recording concerns changes in our Solar System neighbours, the planets. This month, our challenge is to measure the most famous storm of all, the Great Red Spot (GRS) on Jupiter.

Here, visual observation and imaging both work to great effect. The technique you need to master for this challenge is how to make a good estimate of central meridian timings. For this, you'll need a telescope and an accurate timepiece. The telescope needs to be over 150mm aperture to be able to see the Great Red Spot clearly and, as ever, the larger you go the easier this will be.

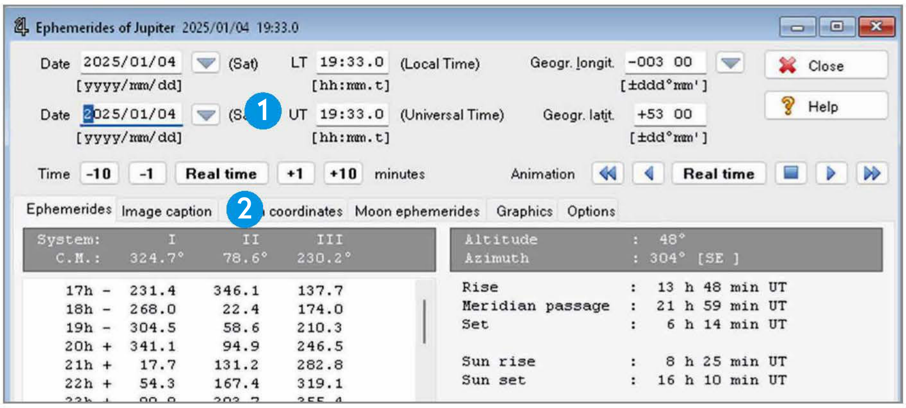
An object's central meridian, or CM, is an imaginary line down the centre of the object as you look at it. For Jupiter, this is the invisible line connecting the planet's north pole to its south pole and, despite not being something you can see tangibly, your eye is pretty good at estimating its position whether at the eyepiece or on an image.

As Jupiter rotates on its axis, atmospheric features such as the GRS will approach the CM and at some point their leading edge (sometimes called preceding edge) will touch it. This is where you make your first measurement, recording the time, as accurately as possible, as the leading edge sits on the CM.

Then it's a matter of waiting until the following edge catches up to also pass the CM. Fortunately, for Jupiter you don't have to wait too long as the planet's rapid, sub-10-hour spin rate moves features surprisingly quickly across the imaginary meridian line. Once the following edge reaches the CM, record that time too.

Now, using a program such as WinJUPOS (freeware), choose Jupiter from the 'Program › Celestial body' option, then 'Tools › Ephemerides'. Change the date and time to match your first recorded time, the one where the leading edge passed the CM. Under the 'Ephemerides' tab, look up the 'System II CM' value. This is the Jovian system II longitude of the GRS's leading edge. Repeat the process for the following edge and obtain its system II longitude too. Ignore system I, as this is for the equatorial zone, and system III refers to the planet's magnetosphere.

Finally, calculate the GRS's longitude span by subtracting the following edge longitude from the preceding one. Multiply this value by 1,187 and this will give you the kilometre width of the GRS. Recently, the Great Red Spot has been shrinking in width. Now you are set to record this variation for yourself.



Date 2025/01/04 (Sat) [yyyy/mm/dd] LT 19:33.0 (Local Time) [hh:mm.t] Geogr. longit. -003 00 [±ddd°mm']

Date 2025/01/04 (S UT 19:33.0 (Universal Time) [hh:mm.t] Geogr. latit. +53 00 [±dd°mm']

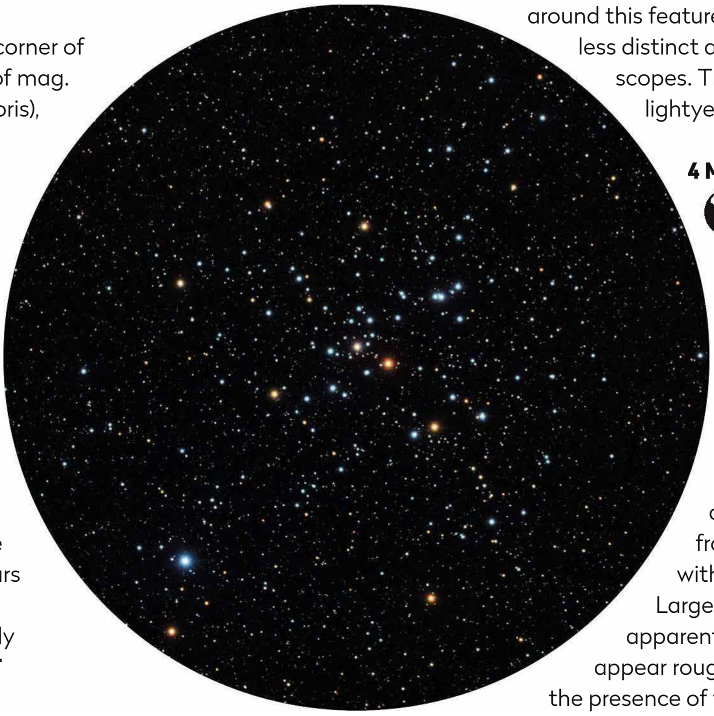
```
System:      I       II      III          Altitude          :  48°
  C.M.:   324.7°   78.6°   230.2°         Azimuth           : 304° [SE ]

   17h -  231.4    346.1    137.7         Rise              :  13 h 48 min UT
   18h -  268.0     22.4    174.0         Meridian passage  :  21 h 59 min UT
   19h -  304.5     58.6    210.3         Set               :   6 h 14 min UT
   20h +  341.1     94.9    246.5
   21h +   17.7    131.2    282.8         Sun rise          :   8 h 25 min UT
   22h +   54.3    167.4    319.1         Sun set           :  16 h 10 min UT
```

▲ **Using WinJUPOS, you can calculate the system II longitude of the leading and following edges of the Great Red Spot. 1) Enter the observation date and time 2) Read off the system II longitude value (here shown as 78.6°). Repeat for leading and following edges of the GRS, then calculate the difference and multiply by 1,187 to obtain the GRS width in kilometres**

DEEP-SKY TOUR

Find a clear horizon for our tour of low-altitude beauties in Canis Major and Lepus this month



▲ **Target number four on this month's tour, bright and colourful M41 is a winter marvel you won't want to miss**

CEDIC TEAM/CHRISTOPH KALTSEIS/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 IC 2165

Located in the northwest corner of Canis Major, 5° due north of mag. +2.0 Mirzam (Beta (β) Canis Majoris), is the planetary nebula IC 2165. Shining at a respectable mag. +10.6, it's easy to overlook due to its small size of 9 x 7 arcseconds. It appears just like a star at magnifications below 150x, only really starting to appear like a true planetary nebula at powers of 250x or above. IC 2165 reacts to an OIII filter really well; one way to confirm you've got it is to move such a filter in and out of your view, the planetary staying put as the stars around it fade. At 400x magnification, it appears roughly 6 arcseconds across. ☐ **SEEN IT**

2 NGC 2204

You'd think our next target would be a little easier. NGC 2204 is a mag. +8.6 open cluster located 1.8° west-southwest of Mirzam. Easy to find and relatively bright on paper at least, the 20+ stars here appear quite faint even through 250–300mm scopes, appearing more like an unresolved glow approximately 20 arcminutes across. Discovered by William Herschel in 1785, NGC 2204 lies 13,400 lightyears from the Sun. If you have a large aperture scope, see if you can resolve any of the cluster members. Although tricky to do, a 300mm scope should be able to pick out around 35 members fainter than mag. +12.5. ☐ **SEEN IT**

3 NGC 2207 and IC 2163

We're doing the rounds of different types of deep-sky objects on this tour, our next target being the mag. +10.7 galaxy NGC 2207. Located 2.8° due south of NGC 2204, NGC 2207 is not alone as it's interacting with fainter mag. +13.5 galaxy IC 2163. They're separated by 1.4 arcminutes and both are spirals presenting themselves relatively face-on. This means their surface brightness is lower than their integrated magnitudes may suggest. It's the core of NGC 2207 that is most obvious, larger apertures possibly revealing the innermost spiral ring around this feature. The core of IC 2163 is much less distinct and troublesome for smaller scopes. These galaxies are 80 million lightyears away. ☐ **SEEN IT**

4 M41

Our final Canis Major target raises the brightness stakes. M41 is a beautiful open cluster with an integrated magnitude of +4.5. It's visible to the naked eye 4° south of Sirius (Alpha (α) Canis Majoris). A 150mm scope shows about 50 stars scattered across an area 0.5° across, ranging in brightness from eighth to 12th magnitude, with many close pairs visible. Larger apertures will increase the apparent size of the cluster, making it appear roughly 50 per cent larger due to the presence of fainter outer members. M41 is 2,300 lightyears from the Sun and is sometimes referred to as the Little Beehive Cluster. ☐ **SEEN IT**

5 IC 418

For our next target we hop across the border into Lepus. Located 2° east-northeast of mag. +4.3 Lambda (λ) Leporis lies the mag. +9.3 planetary nebula IC 418, also known as the Spirograph Nebula. It gets its nickname from high-resolution images which show extremely delicate structures rippling throughout. With an overall size of 14 x 11 arcseconds, IC 418 requires a bit of magnification to see as a distinctive planetary, amateur scopes revealing around 10 arcseconds of its true apparent size. Its central star shines at mag. +10.3 and is clearly visible through a 150mm scope despite the relatively bright surrounding nebula. IC 418 only starts to show a slight elongation through larger apertures. ☐ **SEEN IT**

6 M79

Our final target takes us to low declination in the southern regions of Lepus. Found 3.9° south and 0.8° west of Nihal (Beta (β) Leporis), M79 is a mag. +7.8 globular cluster 0.7° east-northeast of a mag. +5.0 star. At declination –24.5°, you'll need to wait for Lepus to be due south for the best view. Despite this, a 150mm scope should resolve some of the cluster members at magnifications over 100x, a larger aperture doing a great job of resolving many more. Despite its overall apparent diameter of 9 arcminutes, low altitude leading to atmospheric extinction will probably reduce this to 2–3 arcminutes. M79 is around 42,000 lightyears distant. ☐ **SEEN IT**

This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can take you to this month's targets at the touch of a button. Find the Deep-Sky Tour file in our free Bonus Content online.

EQTOUR V1.17
Sync

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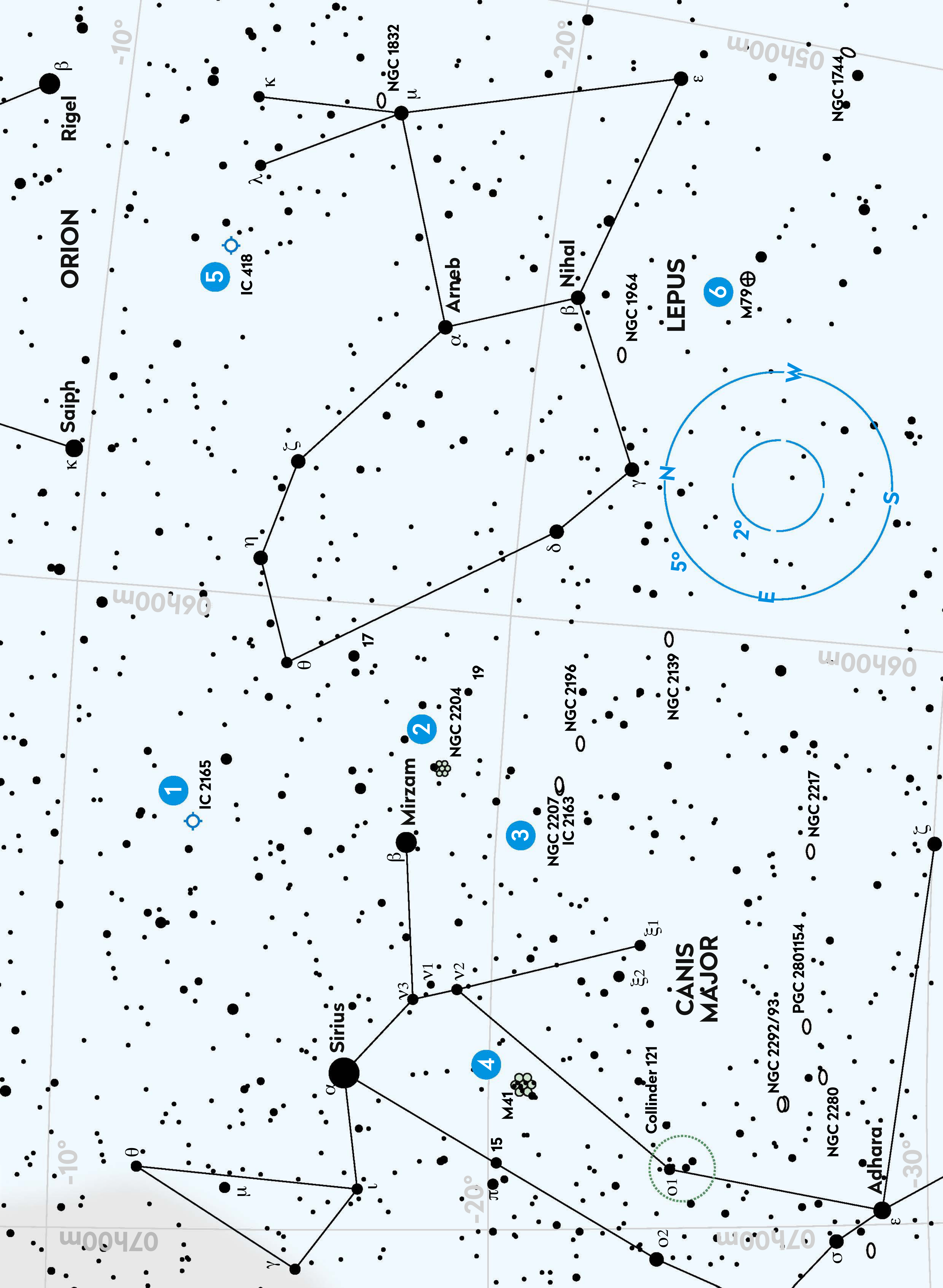
Print this chart and take the Go-To tour

www.skyatnight magazine.com/ bonus-content


ORION
Rigel
Saiph
LEPUS
Arneb
Nihal
CANIS MAJOR
Mirzam
Sirius
Adhara
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NGC 1744
NGC 1964
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NGC 2139
NGC 2207
IC 2163
NGC 2217
PGC 2801154
NGC 2292/93
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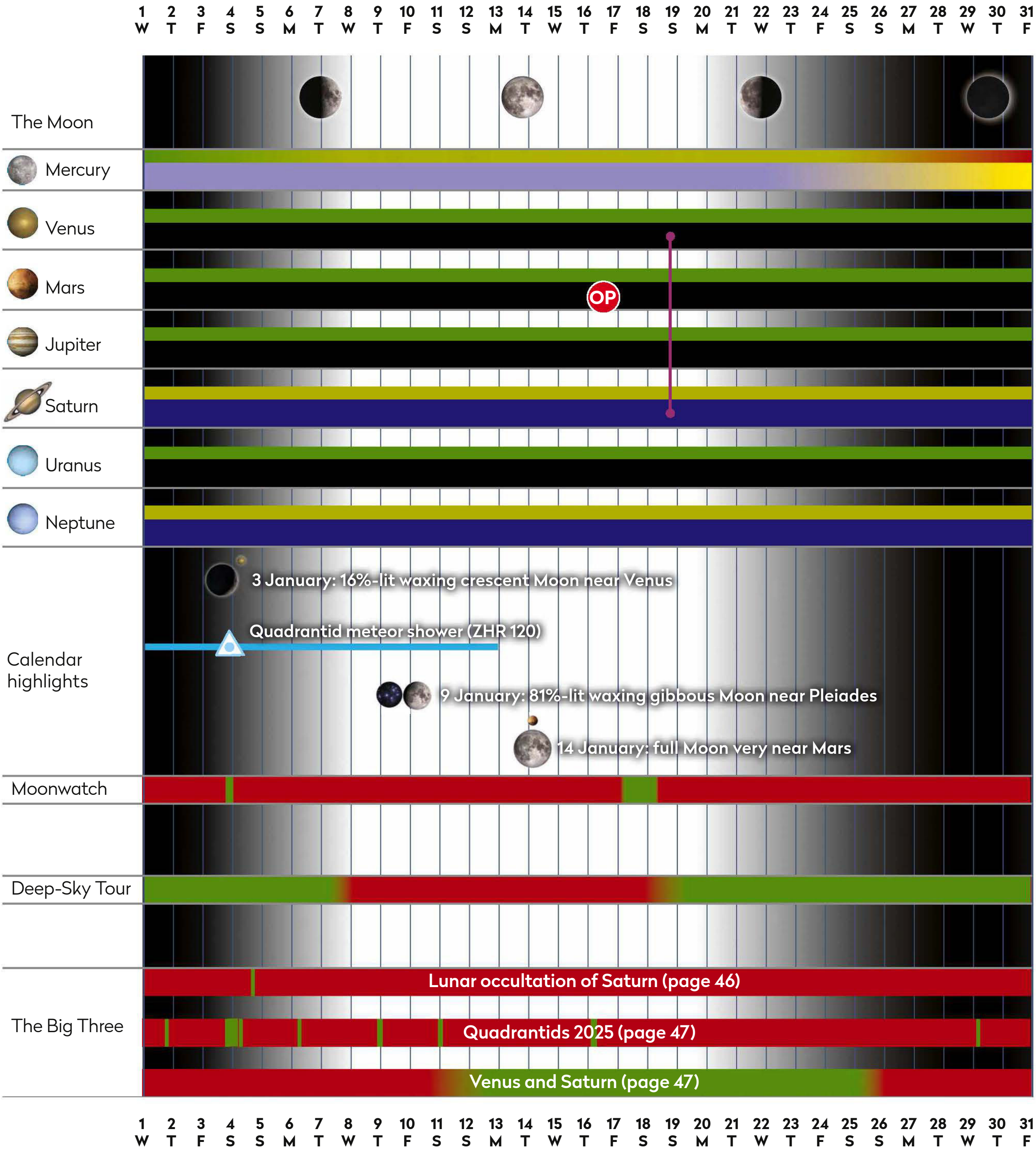
AT A GLANCE

How the Sky Guide events will appear in January



KEY

Observability 🟩 Optimal 🟥 Poor

Best viewed Morning twilight · Daytime · Evening twilight · Night

Sky brightness during lunar phases Dark (first quarter) · Light (full Moon) · Dark (last quarter) · Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

△ Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

Sega Toys
Homestar Flux
Satin Black

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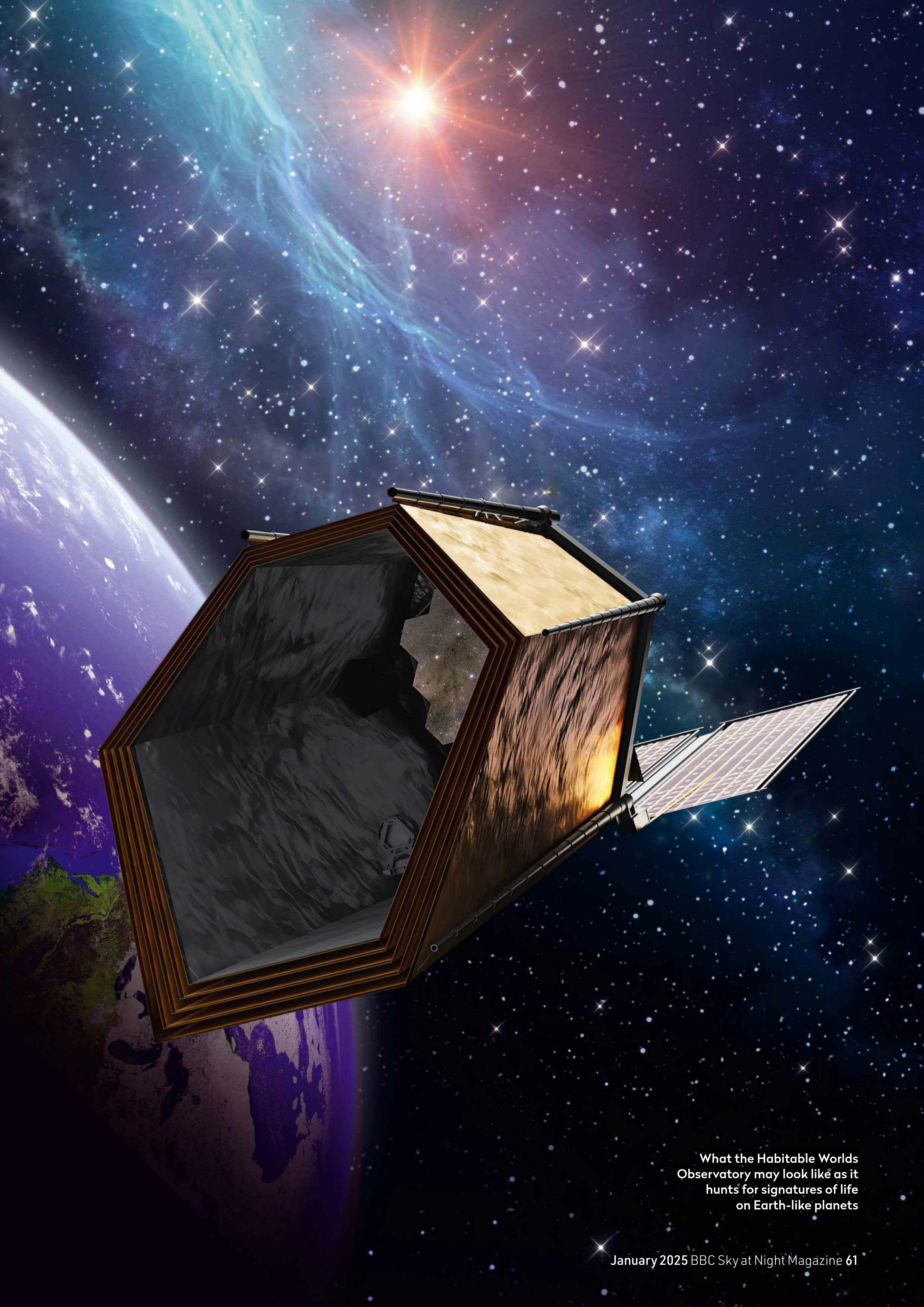
Life SEEKER

In just 20 years from now, the Habitable Worlds Observatory may find evidence for extraterrestrial life. **Govert Schilling** reports as the project takes shape

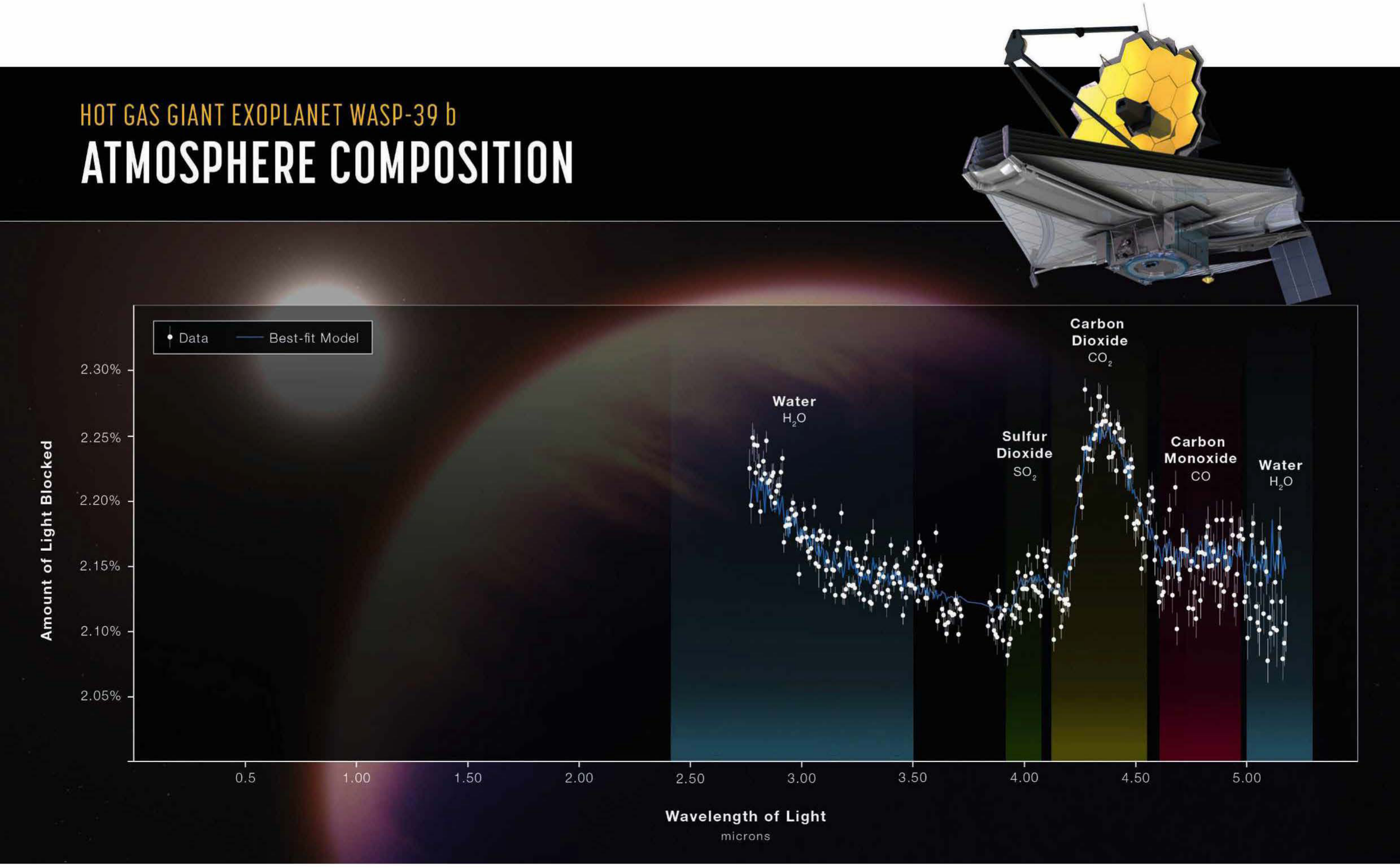
ILLUSTRATION: TITOONZ/ISTOCK/GETTY, NASA'S SCIENTIFIC VISUALIZATION STUDIO

Is there life beyond Earth? No one knows, but most scientists think it's almost inevitable. Our Universe is incredibly extended, both in space and in time, so anything that can happen – in this case, the emergence of life – is almost bound to happen more than once. Moreover, the Universe teems with planets, and the organic building blocks of life appear to be found wherever we look. Even though we don't know precisely how the first living cells were formed, it's extremely unlikely that the process occurred just once.

Still, as yet there's no convincing evidence of life beyond Earth. But that may change in the next two decades or so with the launch of the Habitable Worlds Observatory (HWO), a powerful future space telescope that's currently on the drawing board. On 1 August 2024, the project entered 'pre-Phase A', with the opening of the HWO Technology Maturation Project Office at NASA's Goddard Space Flight Center in Greenbelt, Maryland. According to NASA, the space observatory will be "the first specifically engineered to identify habitable, Earth-like planets… and examine them for evidence of life". ▶



What the Habitable Worlds Observatory may look like as it hunts for signatures of life on Earth-like planets



▲ While JWST can unpick the atmospheres of larger worlds, the Habitable Worlds Observatory will specialise in finding signs of life on Earth-like planets

▶ Since the first discovery of a planet orbiting a Sun-like star back in 1995, astronomers have uncovered more than 7,000 extrasolar planets, or 'exoplanets' for short. Although small low-mass planets like Earth are much harder to detect than gas giants like Jupiter, quite a few have been found. They include Proxima b, orbiting the closest star to our Sun, and the seven worlds circling the star TRAPPIST-1 (around 40 lightyears away), three of which are located in the star's habitable zone, where surface temperatures allow the existence of liquid water. In our Milky Way Galaxy alone, there may be 20 billion similar potentially habitable planets.

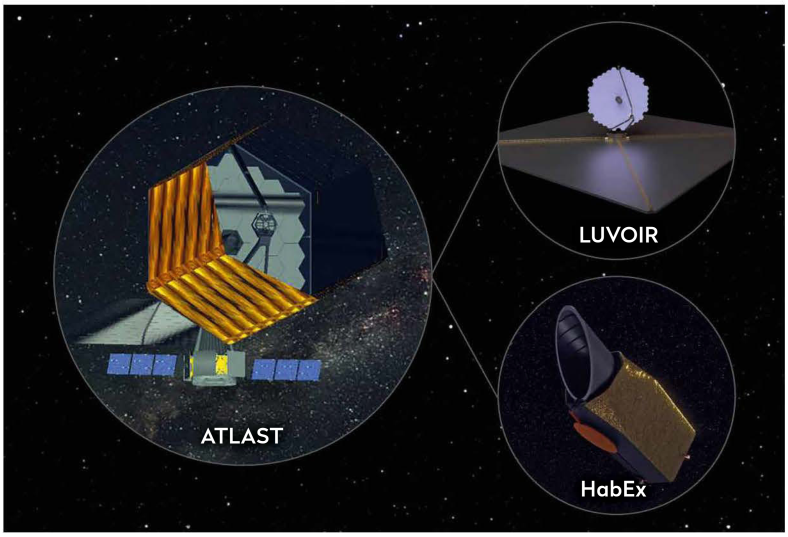
Messages in starlight

So how do you check remote exoplanets for life? The keyword here is 'biomarkers', chemicals in a planet's atmosphere, like oxygen, ozone and methane, that suggest biological activity on the surface. The relative abundance of these three molecules in the atmosphere of Earth, for example, cannot be explained by any non-biological process. Biomarkers leave tell-tale fingerprints in the light of an exoplanet's host star when the planet moves in front of its star: the star's light also contains light reflected by the planet. Sniffing out an exoplanet's atmosphere with spectroscopy may thus reveal the existence of life, even though it wouldn't tell us if we were dealing with microorganisms, plants or aliens.

Using this transit spectroscopy, the James Webb Space Telescope (JWST) has already detected carbon dioxide, water vapour and sulphur dioxide (among other molecules) in the atmospheres of giant, gaseous exoplanets and so-called super-Earths. However, similar measurements on potentially habitable, rocky Earth-like planets are incredibly difficult, and JWST certainly isn't powerful enough to carry out reflectance spectroscopy on small planets. That's why astronomers are looking forward to the Habitable Worlds Observatory. "Detecting life signatures would be the biggest revolution since Copernicus," says Mark Chaplin, NASA's director of astrophysics.

The history of HWO goes back at least 15 years, when Goddard scientists presented plans for a huge 8- to 16-metre Advanced Technology Large-Aperture Space Telescope (ATLAST). These ambitious ideas later developed into two more realistic concept studies: the Large Ultraviolet Optical Infrared Surveyor (LUVOIR), led by Goddard, and the Habitable Exoplanet Observatory (HabEx), led by NASA's Jet Propulsion Laboratory. HWO would

▼ Years in the making: HWO will build on ideas from three earlier NASA concepts



NASA/ESA/CSA/JOSEPH OLMSTED (STSCI), NASA X 3, NASA/DESIREE STOVER, SHACIL/ISTOCK/GETTY, NASA'S SCIENTIFIC VISUALIZATION STUDIO

▲ **HWO will use deformable segmented mirrors similar to those on JWST**

combine elements from both, focusing not only on the search for biomarkers, but also on astrophysics (see From Big Bang to biomarkers, below). The new facility received a strong endorsement from the latest Decadal Survey on Astronomy and Astrophysics (2020), a community-driven recommendation on US government funding.

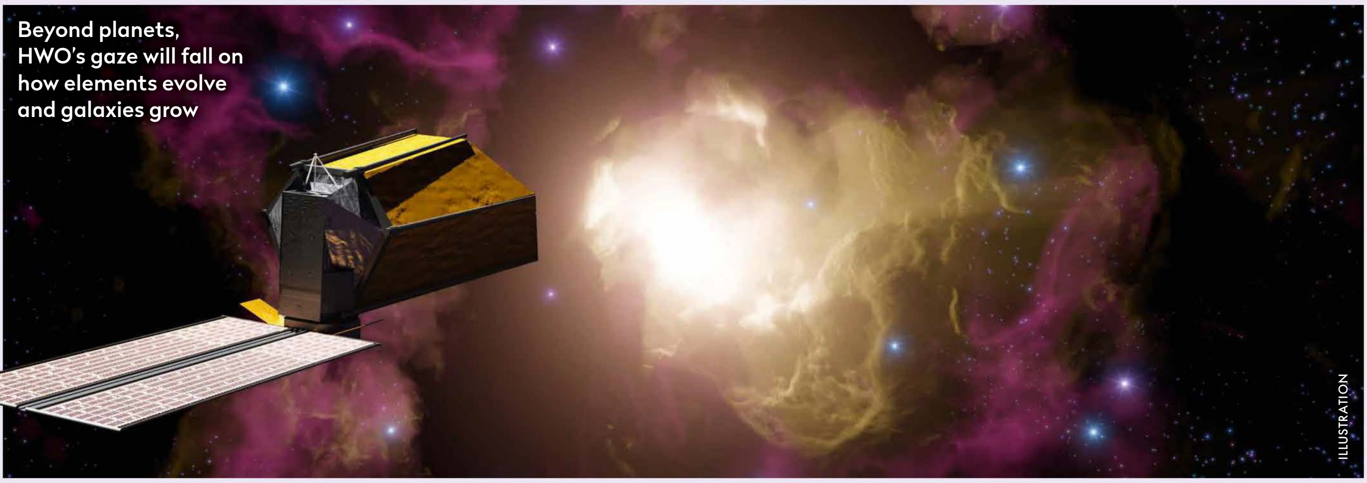
"It's a super-Hubble"

The Habitable Worlds Observatory will probably not launch before the first half of the 2040s. A powerful rocket like NASA's Space Launch System, SpaceX's Starship or Blue Origin's New Glenn will send the telescope to Lagrange 2 (L2), a region some 1.5 million kilometres (0.9 million miles) 'behind' the Earth, as seen from the Sun (and also home to the James Webb Space Telescope). HWO's primary mirror will be at least six metres in diameter, so it needs to be segmented one way or another. However, no decisions have yet been made on the detailed design of either mirror, telescope or spacecraft.

What has been decided, however, is that HWO will cover the same broad wavelength range as the Hubble Space Telescope, from ultraviolet through the optical into the infrared. "It's basically a super-Hubble," says astrophysicist Kevin France from the University of Colorado. At least three large scientific ▶

From Big Bang to biomarkers

Far from being a one-trick pony, HWO has multiple ambitious science goals

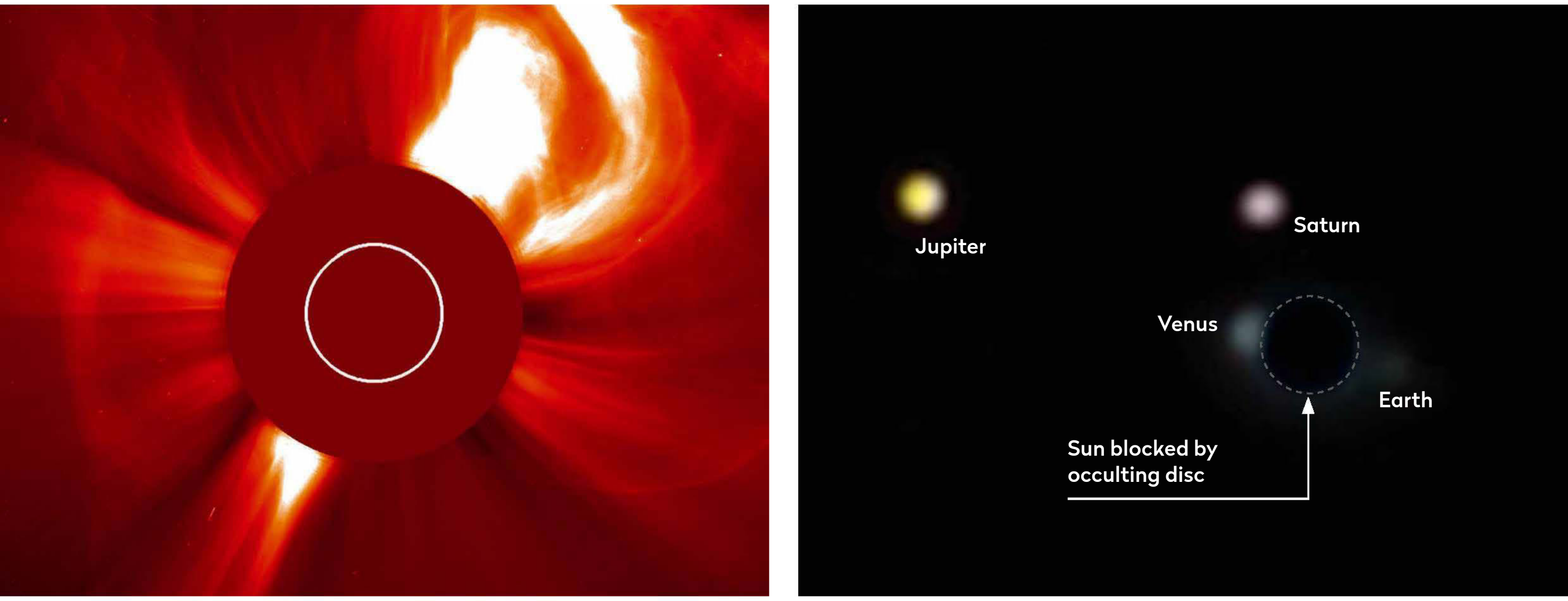


Beyond planets, HWO's gaze will fall on how elements evolve and galaxies grow

The primary goal of the Habitable Worlds Observatory is to look for biomarkers in the atmospheres of Earth-like exoplanets that would indicate the presence of life. But the future space telescope will do much more. Scientists have formulated four major themes for the observatory: drivers of galaxy growth; the evolution of elements over cosmic time; the Solar System in its galactic context; and living worlds. As astrophysicist Kevin France says: "HWO does a little bit of everything."

With its unprecedented sensitivity, the huge observatory will resolve stellar populations of many galaxies beyond our Milky Way, obtain ultraviolet spectra of millions of individual sources and image cosmological deep fields four times faster than JWST does.

Detailed observations of supernovae and star-forming regions will shed more light on the so-called baryon cycle: the way in which the chemistry of the Universe gets enriched over time, eventually leading to the origin of life. And in our own Solar System backyard, HWO will be able to resolve details on large asteroids and planetary moons.



▲ **Left: an image of our Sun taken by the Solar and Heliospheric Observatory (SOHO), using a disc to block its glare. Right: how HWO might discover Earth 2.0 – a simulation showing our Solar System from 33 lightyears away when a coronagraph blocks the starlight**

▶ instruments are foreseen: a high-resolution, widefield (3 x 2 arcminutes) imaging camera with dozens of filters to single out specific wavelengths; an ultraviolet multi-object spectrograph; and a coronagraph that can block starlight to reveal the faint images of closely orbiting exoplanets. "A fourth instrument still has to be defined," says France.

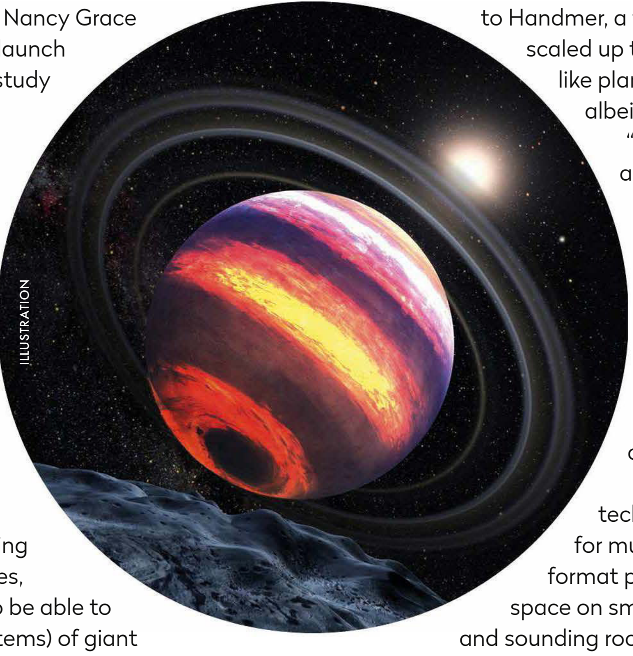
"Apart from imaging at least 25 nearby habitable planets, HWO will also be able to detect Earth-like moons of giant extrasolar planets"

For exoplanet studies, the coronagraph will be the most important instrument. In the past, similar instruments (albeit much less sophisticated) were used to image the Sun's corona by blocking the bright light of the Sun's disc. NASA's Nancy Grace Roman Space Telescope, slated for launch in 2027, also uses a coronagraph to study exoplanets, so by the time HWO is built, engineers will have ample experience with the technology. However, in order to obtain a spectrum of an Earth-like planet in the habitable zone of a nearby star, HWO's coronagraph must reach a contrast of 10–10: it should be able to image a planet that is 10 billion times fainter than its host star.

Planets in close-up

Apart from imaging at least 25 nearby habitable planets and studying the composition of their atmospheres, scientists believe that HWO will also be able to detect Earth-like moons (or ring systems) of giant extrasolar planets, and observe mutual transits and eclipses of giant planets and their moons.

Casey Handmer, a former NASA JPL software system architect, even told the website payloadspace.com that he believes the current HWO approach is pretty conservative. According to Handmer, a future space telescope could be scaled up to detect surface details on Earth-like planets like oceans and continents, albeit at a very low resolution.



▲ **HWO will be able to see ring systems, and even transits and eclipses by exoplanet moons**

"HWO is still a long way off," says astrophysicist Paul Scowen at Goddard. "Many new technologies still have to be developed and demonstrated."

Chaplin agrees. "First we need to mature the various technologies," he says. "Once we understand what exactly we're building, we'll start the detailed design, so as to reduce risks."

According to Scowen, some technologies, including micro-mirrors for multi-object spectroscopy and large-format photon detectors, will be tested in space on small-scale platforms like CubeSats and sounding rockets. "A lot of preparatory work has been done already," he says.

The European Space Agency (ESA) is interested in becoming a partner in the project, just like it is in Hubble and the JWST. "The goals of ESA's long-term science plan, Voyage 2050, are very compatible with the major science themes of HWO," says Ana

SOHO (ESA & NASA), R. JUANOLA PARRAMON/N. ZIMMERMAN/A. ROBERGE (NASA GSFC), ELEN11/ISTOCK/GETTY, NASA, LEV SAVITSKIY/ISTOCK/GETTY, AIRBUS, ESA/ATG MEDIALAB

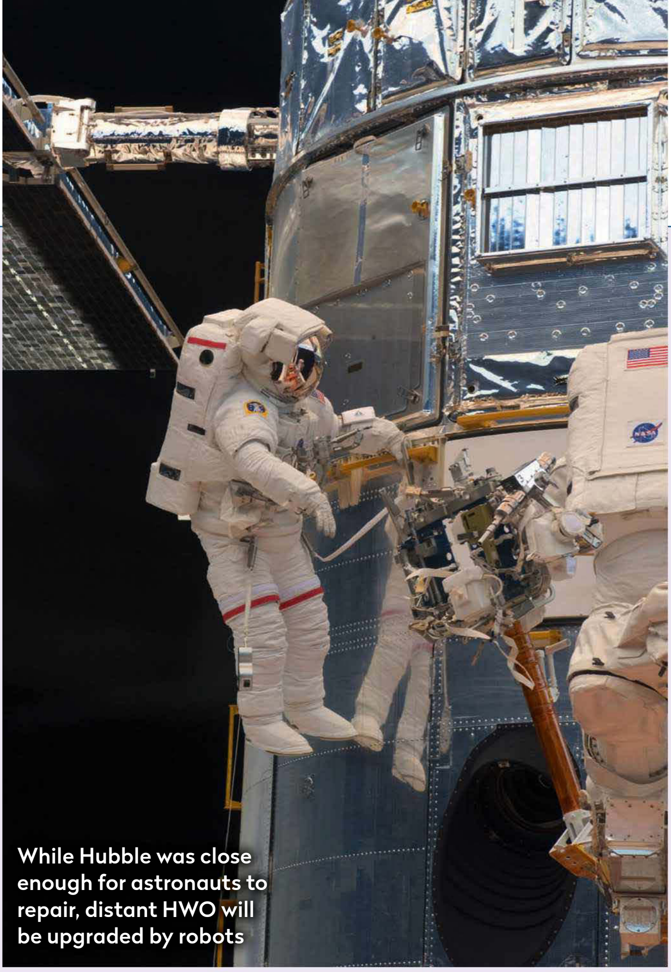
Future proofing

Despite being 1.5 million kilometres from Earth, scientists will be able to robotically service and repair HWO

The Hubble Space Telescope, launched into low Earth orbit back in 1990, has been in operation for decades thanks to five servicing missions, the last one of which took place in 2009. Space Shuttle astronauts have replaced malfunctioning gyroscopes and computers and outfitted Hubble with new solar panels, cameras and spectrographs.

In contrast, the James Webb Space Telescope, which doesn't orbit Earth, cannot be serviced. Once an important component breaks down, the mission will be over.

Like JWST, the Habitable Worlds Observatory will operate from L2, a region in space almost four times more distant than the Moon. Nevertheless, engineers plan to design it in such a way that it can be serviced – not by astronauts, but by robots. An uncrewed mission would fly to L2, rendezvous with HWO and carry out necessary repairs or replacements. What's more, a key purpose of such a mission would be to install a possible second generation of science instruments, upgrading the spacecraft's capabilities.



While Hubble was close enough for astronauts to repair, distant HWO will be upgraded by robots

Gómez de Castro of the Universidad Complutense, Madrid, one of three ESA representatives in the HWO project. According to Gómez de Castro, ESA could contribute a fourth large science instrument for the new space observatory: a high-resolution ultraviolet spectropolarimeter that would study polarised light from exoplanets, as well as from stars and galaxies.

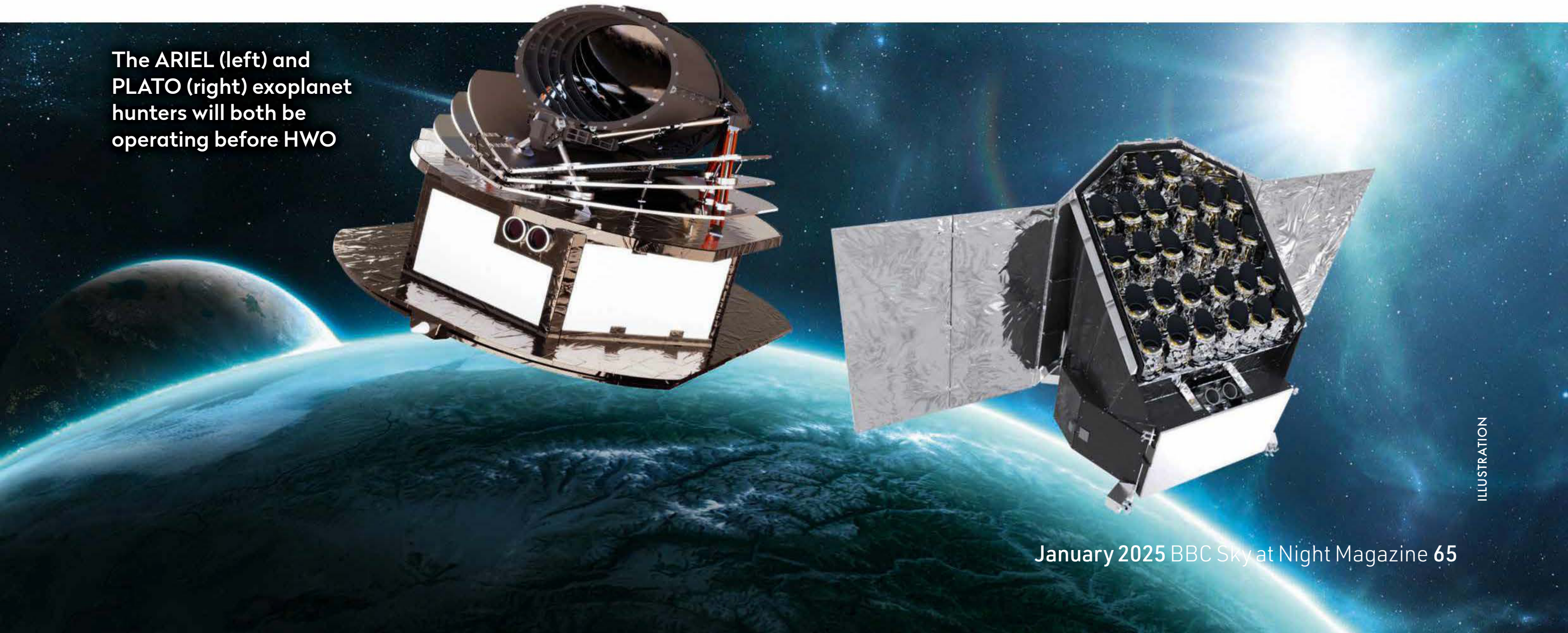
The path to launch day

To coordinate the early work on the Habitable Worlds Observatory, NASA established a Science, Technology, Architecture Review Team (START) and a Technical Assessment Group (TAG), both within the larger Great Observatory Maturation Program (GOMAP). In addition, there's a Smallsat Technology Accelerated Maturation Platform (STAMP), also funded through GOMAP, that will oversee in-space technology demonstration missions.

Govert Schilling is a space science writer and author of *The Astronomy Handbook*

"We're preparing ourselves for Phase A," says Kevin France. That's the phase in which a proposed mission and system architecture is developed. While Phase A could kick off in the next two years, a definitive green light for HWO is not expected before the early 2030s.

By then, two large European exoplanet missions will be operational: PLATO, expected to launch in 2026, and ARIEL (2029). While PLATO (Planetary Transits and Oscillations of Stars) will focus on new detections, ARIEL (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) will study around 1,000 exoplanets in great detail to learn about their atmospheric characteristics. Both will help lay the groundwork for the Habitable Worlds Observatory – which may well be the most exciting and revolutionary space telescope ever. After all, it could potentially answer humankind's profoundest question: are we alone?



The ARIEL (left) and PLATO (right) exoplanet hunters will both be operating before HWO

ILLUSTRATION

NASA

When will we get BACK TO THE MOON?

50 years after the Apollo landings, humanity is at last preparing to return to the Moon. **Ben Evans** investigates why it's taken so long to go back

In November 2022, a slumbering Florida shook under the guttural growl of the world's mightiest rocket – NASA's Space Launch System (SLS). Generating 8.8 million pounds of thrust at liftoff, it turned night into day, eclipsing the Saturn V as the biggest, beefiest and baddest machine ever built. Its uncrewed Artemis I flight test boosted an Orion capsule on a 25-day, 2 million km (1.3 million mile) trek around the Moon – the first time in five decades that we'd seen a deep-space mission made by a ship built for astronauts. Artemis I afforded a much-needed stimulus for NASA's plan to return humans to our nearest celestial neighbour by 2024.

Sadly, as 2025 begins, that vaunted deadline has come and gone.

Artemis's slow progress, decade-long development and eye-watering $93 billion price tag weighs poorly against our last lunar adventure – Project Apollo. ▶

It's been 52 years and counting since Gene Cernan, the last Moonwalker, left the Moon. Why did the Space Race turn into the Space Amble?

▲ Left: 16 July 1969, Apollo 11 on its way to making JFK's pledge a reality. Right: after considerably longer on the drawing board, Artemis I lifted off on 16 November 2022 on its successful uncrewed, tech-testing journey 64,373km (40,000 miles) beyond the Moon and back

▶ Back then, the Saturn V moved from blueprints to the launch pad in six years, nimbly sprinting in 20 months from its 1967 maiden flight to boots on the Moon by 1969. It's hard to ignore the stark empirical truth: Artemis is taking far longer to get from A to B than Apollo did.

But a closer look at the history of Apollo tells another story. In 1961, the Soviet Union, once mocked as a ragtag nation of potato farmers, surged to the technological fore by launching the first artificial satellite, putting living animals in space and sending probes to the Moon. These accomplishments raised gnawing anxieties in America of a 'gap' in missile-building know-how. If Russia possessed advanced intercontinental ballistic missiles, they could strike American cities at will. No missile gap actually existed, but the technology wins gave the Soviets a propaganda tool to wield with relish. In April 1961, Yuri Gagarin became the first human in space. President John F Kennedy had to salvage US national pride – and fast. In May, he went public. America would put a man on the Moon by 1970.

Post-Space Race slump

Kennedy knew the Soviets hungrily coveted the same goal. NASA's budget sprang to achieve it, from 0.9 per cent of federal expenditure in 1961 to 4.4 per cent by 1966. But an unpopular war in Vietnam and social unrest at home – racial inequality, poverty, rats in Harlem apartments, illiterate children, the assassination of Martin Luther King – shifted attitudes. In the years after 1966, NASA's budget progressively fell. After the Moon race was ultimately won in 1969 with Apollo 11, change came upon the programme in a brutally brisk fashion: two Apollo missions cancelled, the Saturn V production line shut down, and plans for Moon and Mars bases binned for the Shuttle – a cheaper, more economical spaceship.

Improved détente with the Soviets no longer required a Space Race, distancing successive presidents from the Moon. But after Shuttle Challenger's loss in 1986, Sally Ride, America's first woman astronaut, led a task force to chart NASA's future. Her Ride Report recommended a lunar outpost with a 30-person crew by 2010 and a Mars voyage in the 2020s. By 1989, this vision had grown into the Space Exploration Initiative (SEI), a multi-decade "journey into tomorrow", including a Moon

▼ President George Bush Sr backed the Space Exploration Initiative (SEI) in 1989... until NASA calculated the cost

NASA X 2, NASA/CHRIS COLEMAN/KEVIN DAVIS, ANADOLU/GETTY, NASA JOHNSON

Starship's vital role: taxi to the Moon

SpaceX's Starship will be key to getting humans and materials onto the lunar surface

With Starship's Human Landing System (HLS) set to land people at the Moon's south pole during Artemis III, the development of SpaceX's colossal spacecraft has attracted intense scrutiny. Not only must Starship fly to and from the lunar surface, it requires multiple spacecraft to do so, meaning a high flight cadence is needed to assure the viability of the programme.

Doubts about its feasibility came to a head last summer, when Japanese billionaire Yusaku Maezawa cancelled dearMoon, a tourist mission to circumnavigate the Moon. Maezawa said Starship's lack of "clear schedule certainty" precipitated his decision.

SpaceX is bringing Starship and its Super Heavy booster online by continual success-and-failure testing. The 121-metre (398ft) stack is the tallest rocket ever flown and at liftoff generates 16.7 million pounds of thrust – the most powerful ever. Its first six test flights achieved mixed results: engine glitches and structural failures, juxtaposed with successful in-space fuel transfers and a spectacular controlled return of a Super Heavy from the edge of space back to the launch pad.

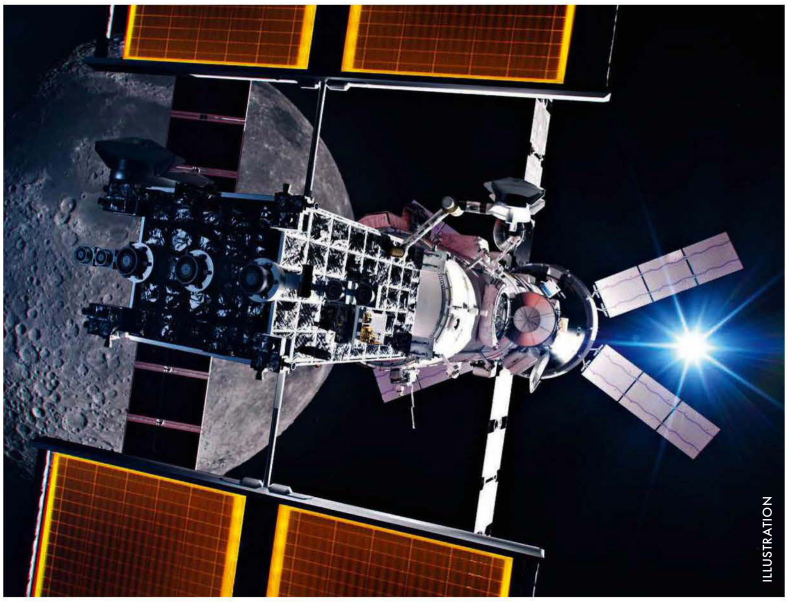
In 2025, SpaceX plans to begin regular in-space refuelling trials and will rapidly ramp up Starship's launch cadence. If Artemis III is to land humans on the Moon, time is of the essence.

Quite the catch: Starship's success hinges on fast turnaround and redeployment

base and Mars mission. Then came the clanger: it would cost $500 billion. The shaky floorboards of political support collapsed. NASA's emphasis tilted next to robotic exploration, a 'Faster, Better, Cheaper' philosophy into which human Moon flights simply did not fit. The 1996 national space policy did not mention humans voyaging beyond Earth orbit.

Next was 2004's Vision for Space Exploration (VSE), a Moon return by 2020 with new crew capsules, lunar landers and heavy-lift rockets. Although criticised as "Apollo on steroids", VSE produced real flight hardware with a test launch of an Ares I rocket booster in 2009.

▼ Multiple countries will need to collaborate to get the lunar Gateway built



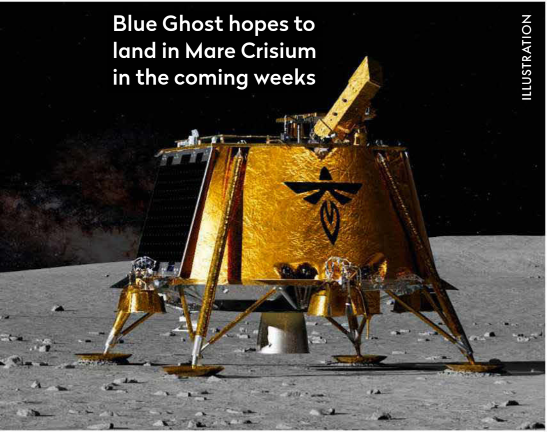
ILLUSTRATION

Sadly, cost undid VSE. It was behind schedule, underfunded and overbudget. In 2010, Barack Obama cancelled it, eliminating a human Moon return. However, in 2011 he authorised building the SLS rocket, advocating a crewed mission to a near-Earth asteroid by 2025 and a Mars voyage in the 2030s.

The age of Artemis

Then, in 2017, Donald Trump tilted US space policy back to the Moon. NASA would now leverage international partners to build a lunar-orbiting Gateway outpost with commercial firms facilitating payload services, landers, rovers and space suits. By 2019, the Moon return had a deadline: 2024. And it had a name: 'Artemis', Apollo's twin sister in ancient Greek mythology. By targeting a single objective, the Moon, NASA avoided 'mission creep', where complicated projects naturally accrue costs and failure becomes more likely.

Private industry would be key to the endeavour. NASA's Commercial Lunar Payload Services (CLPS) initiative funded companies to fly robotic landers and rovers to the Moon before humans. But CLPS began falteringly. One firm dropped out while others were delayed by COVID-19, supply-chain issues, changing landing sites and technical maladies. Last year, Astrobotic's Peregrine 1 sprang a propellant leak after launch, nixing its landing at Gruithuisen Domes on the Moon's Oceanus Procellarum. Then, Intuitive Machines' IM-1 lander alighted near the Malapert-A south pole crater but broke one of its landing legs, tipped over and lost power. ▶


Blue Ghost hopes to land in Mare Crisium in the coming weeks

ILLUSTRATION

▶ Such bumps in the road are part and parcel of high-risk spaceflight. Yet CLPS continues.

"NASA is conducting a comprehensive campaign of lunar science using Moon-orbiting spacecraft, CLPS landings, human missions through the Artemis campaign and US experiments on international robotic spacecraft," explained Alise Fisher of NASA's Science Mission Directorate. "The agency has many upcoming missions and payloads designed to both look for water ice on the Moon as well as to demonstrate our technological capability of drilling for ice should we find it."

Private sector steps in

At time of writing, Firefly's Blue Ghost is due to land at Mare Crisium in late 2024 and Intuitive Machines' IM-2 targets a February 2025 south pole landing with its PRIME ice-mining drill and spectrometer. Astrobotic's Griffin 1 in September 2025 was to fly the VIPER ice-seeking rover, but cost and schedule overruns saw NASA cancel VIPER last July.

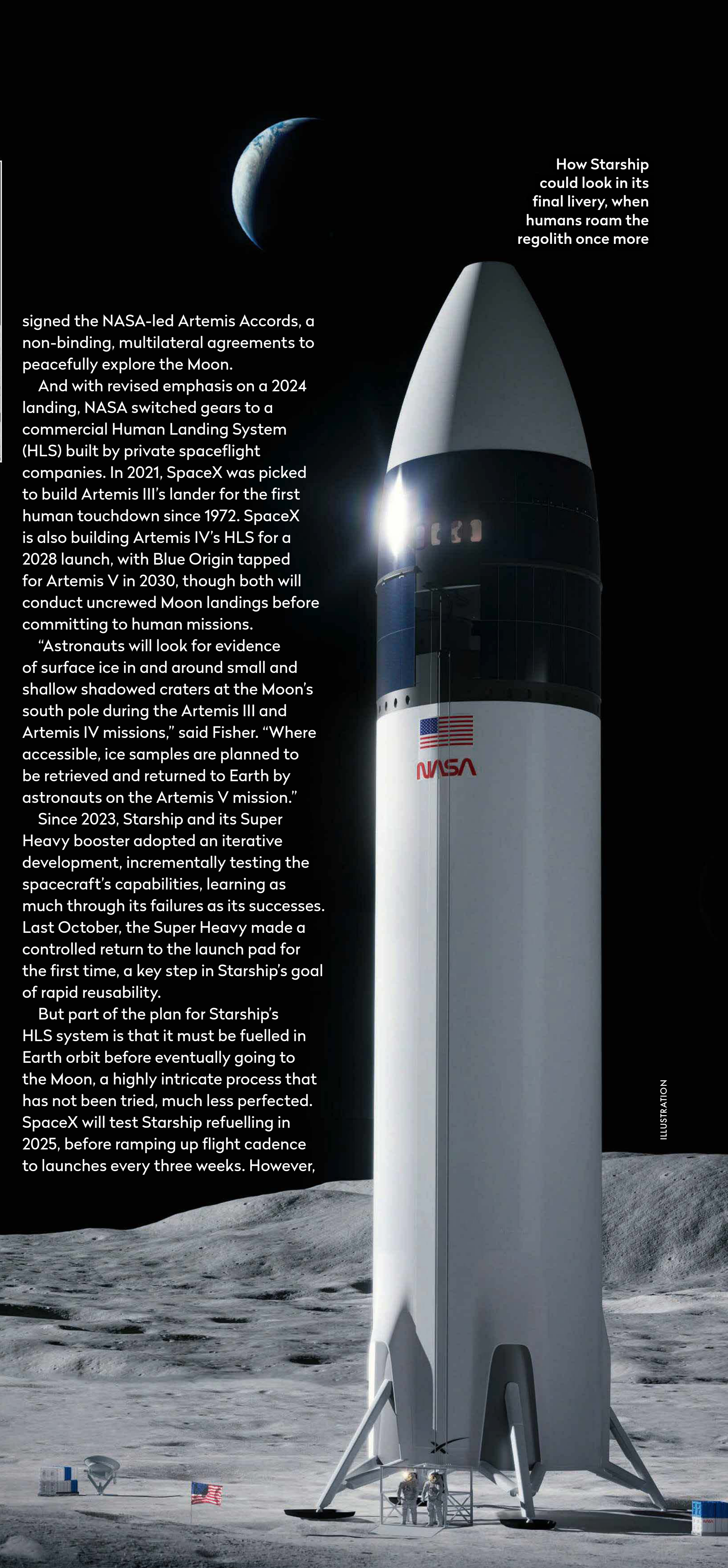
With the US, Canada, Europe, Japan and the United Arab Emirates set to build the Gateway in lunar orbit, at least 47 nations spanning Europe, the Americas, Asia, Africa and Oceania have, since 2020, signed the NASA-led Artemis Accords, a non-binding, multilateral agreements to peacefully explore the Moon.

And with revised emphasis on a 2024 landing, NASA switched gears to a commercial Human Landing System (HLS) built by private spaceflight companies. In 2021, SpaceX was picked to build Artemis III's lander for the first human touchdown since 1972. SpaceX is also building Artemis IV's HLS for a 2028 launch, with Blue Origin tapped for Artemis V in 2030, though both will conduct uncrewed Moon landings before committing to human missions.

"Astronauts will look for evidence of surface ice in and around small and shallow shadowed craters at the Moon's south pole during the Artemis III and Artemis IV missions," said Fisher. "Where accessible, ice samples are planned to be retrieved and returned to Earth by astronauts on the Artemis V mission."

Since 2023, Starship and its Super Heavy booster adopted an iterative development, incrementally testing the spacecraft's capabilities, learning as much through its failures as its successes. Last October, the Super Heavy made a controlled return to the launch pad for the first time, a key step in Starship's goal of rapid reusability.

But part of the plan for Starship's HLS system is that it must be fuelled in Earth orbit before eventually going to the Moon, a highly intricate process that has not been tried, much less perfected. SpaceX will test Starship refuelling in 2025, before ramping up flight cadence to launches every three weeks. However,



How Starship could look in its final livery, when humans roam the regolith once more

ILLUSTRATION

VIPER axed

Despite being ready to go, costs and delays saw the robotic rover cancelled at the last minute

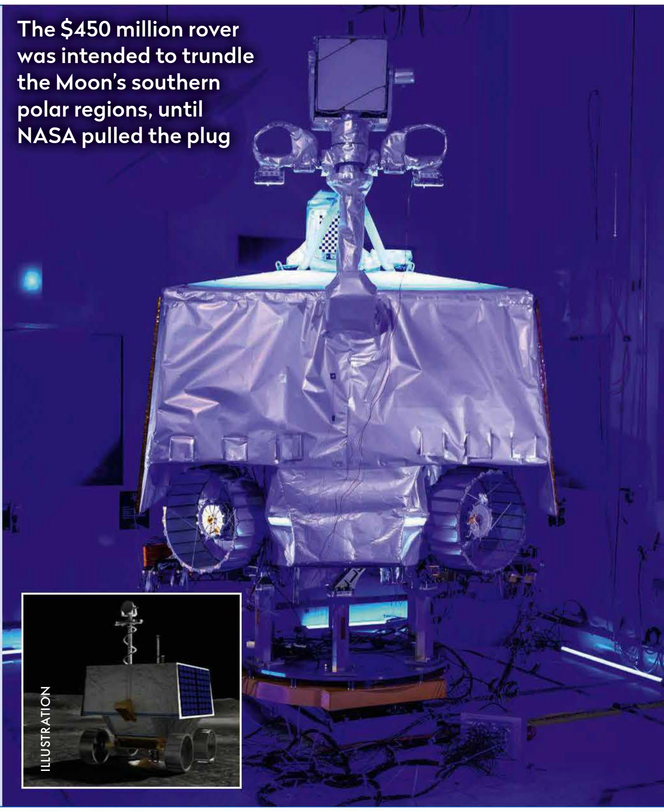
The golf-cart-sized Volatiles Investigating Polar Exploration Rover (VIPER) was to fly on Astrobotic's Griffin 1 lander to the Moon's south pole in September 2025 – until the mission was cancelled last summer.

Equipped with a drill, three spectrometers and its own lighting source, the four-wheeled VIPER was targeted to land at the western edge of Nobile crater. During a planned 100 days on the Moon, the rover would prospect for water-ice and other volatiles, mapping their distribution, depth and purity.

But after mission costs swelled past $450 million and launch slipped from 2024 to 2025, NASA decided to end the mission. Cancelling VIPER reportedly saved $84 million, but the rover was fully built, with its instruments completely integrated and fully tested for launch.

NASA expects VIPER's objectives to be met by other future missions and its hardware may be retasked for future missions, including on the lunar vehicle to be used by Artemis V astronauts. "The instruments from VIPER are candidates for the Lunar Terrain Vehicle," said Fisher.

But VIPER's cancellation was received poorly by the lunar and planetary science community, with the Planetary Society calling for its reinstatement and the House Committee on Science, Space and Technology requesting additional information on NASA's decision to end the mission.


The $450 million rover was intended to trundle the Moon's southern polar regions, until NASA pulled the plug

ILLUSTRATION

Private companies are vying to work on NASA's new Lunar Terrain Vehicle

ILLUSTRATION

congressional watchdog the General Accounting Office indicates there is only a 70 per cent chance it will be ready by 2028.

Dreams with a deadline

After Artemis I, NASA hoped to fly the crewed Artemis II around the Moon in November 2024, then land astronauts near the lunar south pole on Artemis III in December 2025. Last year, it delayed Artemis II until September 2025, citing heat shield, life-support system and battery concerns. Artemis III correspondingly slid to September 2026, but Starship delays mean that might slip again. Later missions will assemble the Gateway, explore the surface and fabricate a long-term, sustainable base in the 2030s.

Artemis has attracted commercial partners, with AxiomSpace, Prada and Nokia developing Artemis space suits, while Toyota, General Motors, Michelin and others vye to build the Lunar Terrain Vehicle, and Goodyear works on bringing airless tyre technology to an airless world.

"The teleoperated Lunar Terrain Vehicle is being designed to be able to enter permanently shadowed regions at the south pole for up to two hours of exploration," said Fisher. "NASA will select science instruments for the Lunar Terrain Vehicle in 2025 and the vehicle is planned to land no later than 2029."

Some question why Saturn V blueprints cannot be dusted off and the old rocket remade. But its 1960s technology has been superseded by modern boosters – SpaceX's Falcon Heavy and Starship, Blue Origin's New Glenn, United Launch Alliance's Vulcan – which are cheaper, safer, more capable, more reliable.

Today, NASA's budget (not just for Artemis) sits at 0.48 per cent of federal spending. While this is just 10 per cent of the federal spending enjoyed by Apollo, it is in a much more stable position, with bipartisan support in Congress. Multiple stakeholders, from treaty-bound national governments to contract-bound commercial partners, also assure the political sustainability needed to achieve long-term goals.

Artemis is taking longer than Apollo did, but at less cost. Adjusted for inflation, Apollo's $25.4 billion price tag equates to $182 billion today, twice Artemis's running total. Apollo's breakneck pace was also fed by a national goal and a looming geopolitical menace that Artemis lacks.

But there's something else. Artemis was marketed to land a woman and person of colour on the Moon, a powerful, visceral image, understandable to all – and a pledge that Artemis is not 'Apollo redux' but new history in the making.

Ben Evans is an astronomy writer and the author of several books on human spaceflight

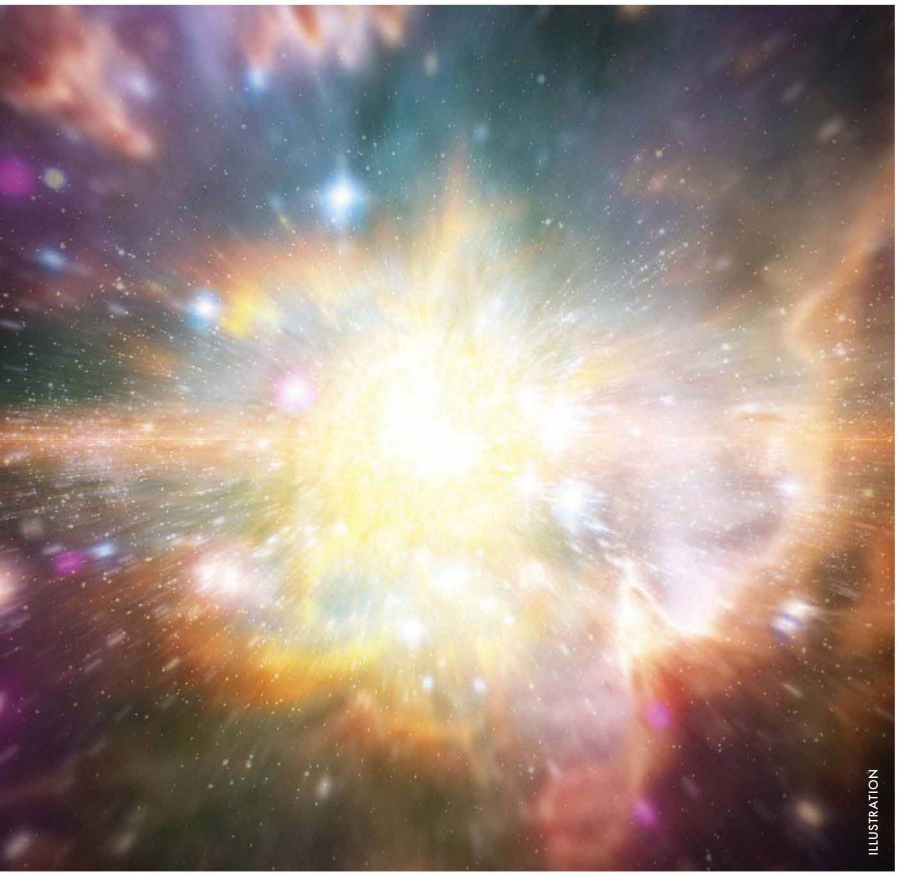
FIREFLYSPACE.COM, SPACE X, NASA X 2, NASA/DANIEL RUTTER

The fundamentals of astronomy for beginners

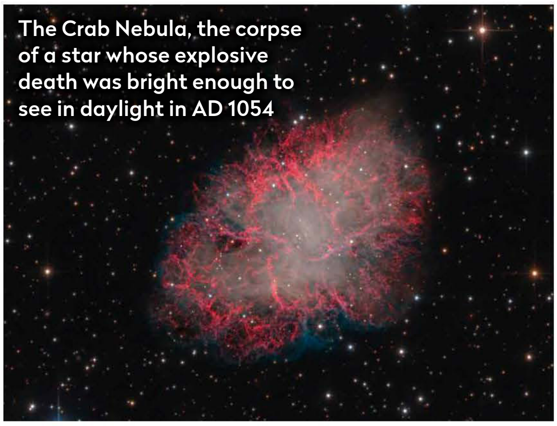
EXPLAINER

Supernovae

Some stars die in a spectacularly powerful and violent fashion. Here's how it happens



▲ While some stars quietly fizzle out at the end of their lives, others go supernova – an explosion so huge that the star briefly outshines its whole galaxy


The Crab Nebula, the corpse of a star whose explosive death was bright enough to see in daylight in AD 1054

A supernova recorded in ancient rock paintings in New Mexico

All stars die. How they die depends in part on their mass, but their deaths can result in titanic and spectacular explosions in space – supernovae – when they briefly outshine their host galaxies and radiate more energy than our Sun will deliver in its lifetime.

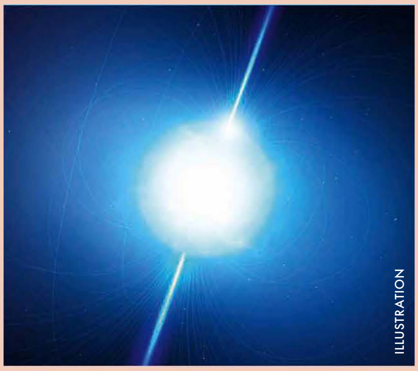
The term 'supernova' was first coined in 1934 by Walter Baade and Fritz Zwicky at the Mount Wilson Observatory in California, when they witnessed an explosive event in the Andromeda Galaxy. But supernovae were being observed long before the invention of the telescope, the oldest being RCW 86 spotted by Chinese astronomers in AD 185 as a 'guest star' visible in the sky for eight months. Perhaps the most famous supernova is the Crab Nebula, captured in AD 1054 by Native Americans in the form of rock carvings in Arizona and New Mexico.

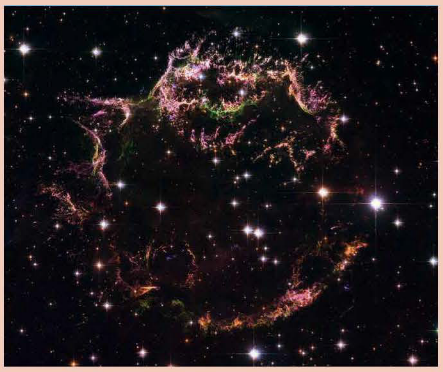
Supernovae broadly separate into two main types and result from either a thermonuclear runaway or a core collapse within a star.

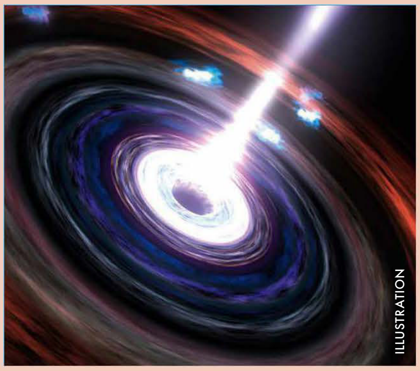
Type Ia supernovae are the result of runaway nuclear reactions. They happen in binary star systems where at least one star is a white dwarf – the small, dense, remnant core of a star that has exhausted its fuel and shed its outer layers in the form of a planetary nebula. A white dwarf has tremendous gravity and will accumulate material from its stellar companion until it reaches the Chandrasekhar Limit, or 1.44 times the mass of our Sun. When it exceeds this, its core heats up, resulting in an excessive and unsustainable amount of energy

Zombie stars, beauty queens and black holes

Once a star has gone supernova, it's destined to live on as one of these three types of object…







NEUTRON STARS

When a Type II supernova of a star with 8–20 times the mass of the Sun occurs, the remnant is a super-hot, ultra-dense collapsed core, a neutron star, where gravity has even squeezed the space from between particles in atoms. It is city-sized but with more mass than our Sun and a magnetic field billions of times stronger. Neutron stars can spin rapidly, hundreds of times per second, emitting regular pulses of radio waves detectable by telescopes – pulsars.

SUPERNOVA REMNANTS

These are the ethereal-looking structures left over from supernovae, which you'll have seen in beautiful astrophotos. They consist of hot gas, plasma and interstellar material swept up by the shockwave of the initial detonation. The shockwave heats and ionises the gas surrounding it to extremely high temperatures, emitting light across various wavelengths. They are also a source of cosmic rays, where the shock accelerates particles to high speeds.

STELLAR-MASS BLACK HOLES

When stars with a mass 20–30 times that of our Sun exhaust their fuel, their cores collapse to almost infinite density to create a black hole. The outer layers may blast into space; the star can be so heavy the shockwave can't overcome the black hole's gravity and the entire star is consumed. These explosions can create long gamma-ray bursts; material is spun up around the black hole and blasts away at close to the speed of light.

and pressure; a runaway nuclear reaction results and the star explodes.

A **Type II supernova** occurs when a star with a mass greater than eight times that of our Sun runs out of fuel and collapses under its own gravity. Having fused its hydrogen into helium, it sequentially burns carbon, neon, oxygen and silicon. There is an energy balance: gravity pulling in, radiation pushing out. But once silicon supplies are exhausted, the core becomes a hunk of iron and no further energy can be released through nuclear fusion.

This brilliant supernova in galaxy NGC 2525 was visible for months in 2018

Rebound effect

Once this critical core density is reached, gravity has the upper hand. With no internal pressure to support it, the outer shell of the star implodes. The collapsing outer layers rebound and detonate as a supernova, violently ejecting the star's material into space. **Type Ib and Ic supernovas** also undergo core collapse just as Type II supernovae do, but they have lost most of their outer hydrogen layer. There are subtypes of each of these supernovae too, classified by the elements visible in their spectra.

To study these explosions, astronomers use telescopes: the Hubble Space Telescope observes Type Ia supernovae billions of lightyears away for hundreds of days after detonation; NuSTAR uses X-ray vision to observe before, during and after events; and ULTRASAT observes in ultraviolet light, detecting explosions within seconds or minutes. Surveys such as the All-Sky Automated Survey for Supernovae (ASAS-SN) and the Dark Energy Survey provide a continuous stream of data from our Galaxy to identify supernovae.

Astronomers also use Type Ia supernovae as 'standard candles' to measure cosmic distances, since they blaze with equal brightness at their peak.

On average, a supernova occurs every 10 seconds in the Universe. Their remnants (see above) heat up the interstellar medium, distributing elements heavier than iron and providing the ingredients for the next generation of stars – a recycling process vital to the ecology of our Galaxy.

Jane Green is an astronomy writer and author of the *Haynes Astronomy Manual*

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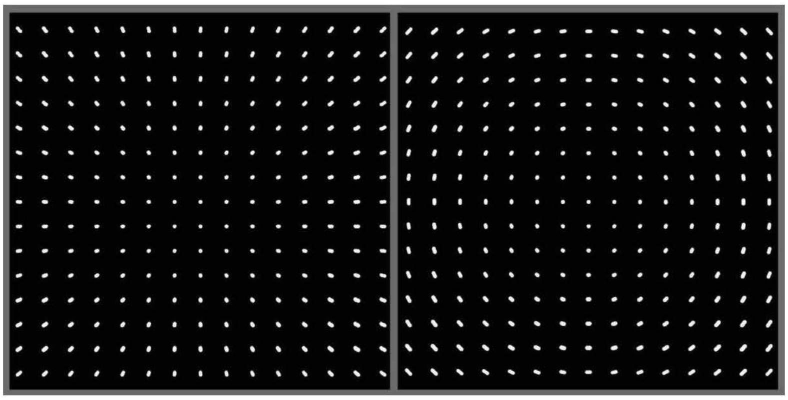
Practical astronomy know-how for every level of expertise

SKILLS FOR STARGAZERS

Set the right back focus for your scope

How to tweak your imaging setup to achieve distortion-free stars from edge to edge

▲ Follow our guide to work out the spacers you need in your imaging train to achieve perfect back focus



▲ Elongated, misshapen stars – particularly at the edges – from a field flattener positioned too close (left) and too far (right) from the camera sensor

Back focus often causes astronomers confusion. In general photography terms, it's the distance from the last glass surface in the optical train to the focal plane of the camera – typically 55mm in DSLRs, for example. For telescopes, back focus is the distance from the outer end of the focuser draw tube (when fully wound in) to the focal plane of the telescope, or – for catadioptric scopes – to the focal plane when the scope is at its designed focal ratio.

Essentially, for telescopes, back focus indicates the space within which you can fit other optical components. It's important to remember that these other optical components, such as filters, Barlow lens and focal reducers, will alter this value slightly.

Most telescope designs produce curved focal planes. Take a Newtonian reflector; this has a curved focal plane with a radius equal to the focal length of the telescope, meaning the shorter the focal length, the greater the curvature. Similarly, shorter refractors produce more curvature than longer ones.

Curved focal planes and flat sensors result in distorted stars at the frame edge. A solution is to use a field flattener, an optical component that makes the focal plane flat. Focal reducers may also have flatteners built in and are called reducer-flatteners.

Many flatteners and reducer-flatteners are specific to particular telescope models and require optimum spacing between their back ends and a camera sensor. This specific distance is referred to as 'required back focus'. The field curvature distortions are less of an issue with planetary imaging setups, where a small imaging area combined with a long focal length means distortions are minimised. Such setups are more forgiving of required back-focus errors.

For widefield imaging, as you'd use for deep-sky vistas, it's important to get the back-focus distance any flattener needs correct, or additional distortions will occur. If the stars are elongated concentrically relative to the centre of the frame, the distance between the flattener and the camera sensor needs to be reduced; if they are elongated radially, the distance should be increased.

These distortions are easy to fix by fitting the correct type of spacer between the camera and the device. Once you're in approximately the right position, you can fine-tune the precise distance by looking at stars in your images and adjusting by small amounts until they look beautifully round right to the edge of the frame.

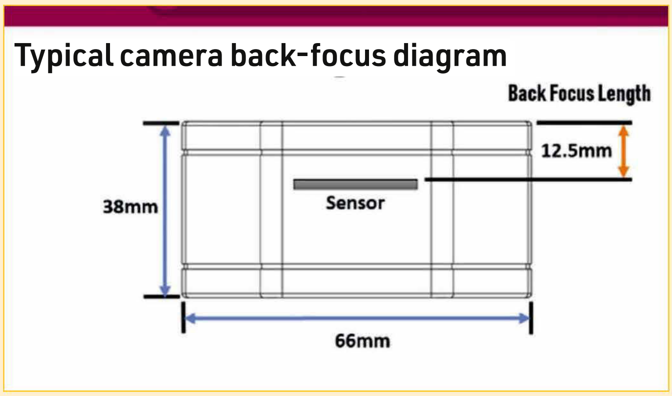
Pete Lawrence is an expert astro-imager and a presenter on The Sky at Night

ALL PICTURES: PETE LAWRENCE

What you'll need

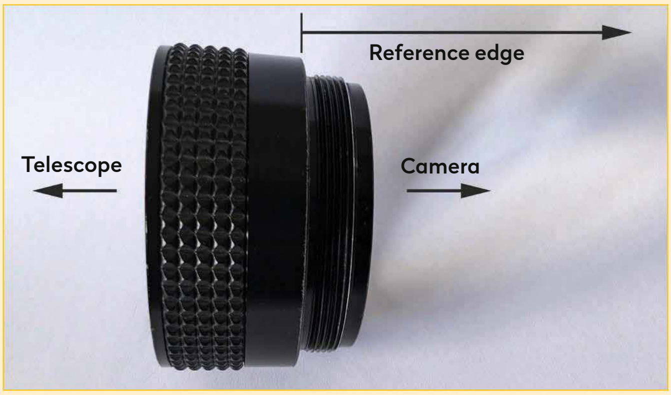
- ▶ Ruler
- ▶ Field flattener or reducer-flattener
- ▶ Manufacturer's information on the required back-focus value
- ▶ Polar-aligned equatorial mount; telescope; deep-sky camera with a large sensor
- ▶ Extension/spacer tubes
- ▶ Fine-tuning rings for precise adjustment
- ▶ A PC and viewing/processing software to magnify and examine the stars

Step by step


Typical camera back-focus diagram
Back Focus Length
12.5mm
38mm
Sensor
66mm

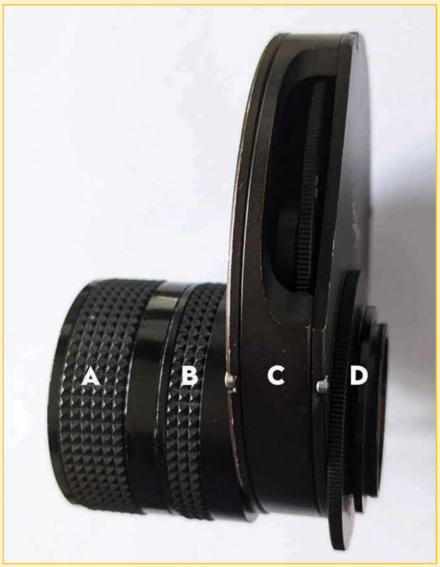
Step 1

Check the documentation for your flattener or reducer-flattener for the required back-focus distance. You'll also need to know the position of your camera model's sensor relative to the camera body, which you'll find in the camera's manual or online.


Reference edge
Telescope
Camera

Step 2

Required back focus is usually measured from the flange edge of the flattener/reducer facing the camera, minus the male threads (which disappear into the next component). Confusingly, a few manufactures do measure from these threads, so double-check.

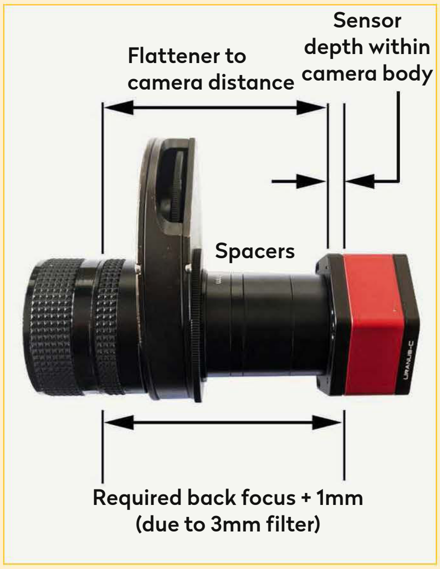


Step 3

The physical thickness of other optical components – such as filters, a filter wheel (C), or adaptors (B and D) – between the flattener (A) and the camera need to be considered and added to the required back-focus distance. For filters, add a third of the filter's thickness.

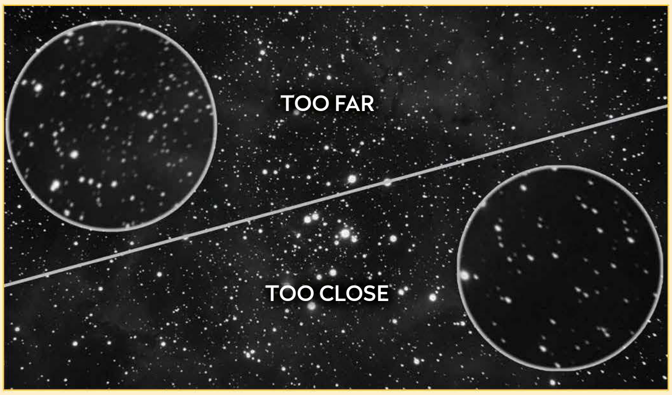
Step 4

Assemble the components, such as filter wheels. Measure from the flattener's reference edge to the furthest non-threaded surface, accounting for any filters. Add the sensor depth (Step 1); subtract the total from the flattener's required back focus.


Sensor depth within camera body
Flattener to camera distance
Spacers
Required back focus + 1mm (due to 3mm filter)

Step 5

The remaining value is the gap that needs bridging with spacers. Spacer rings or T2–T2 adaptors with adjustment rings can be used to refine the total distance as accurately as possible. There are also specialised back-focus adjusters that provide additional fine-tuning control.


TOO FAR
TOO CLOSE

Step 6

Take test shots and examine the frame edges. Do the stars look distorted? If you have the distance correct, they'll appear round across the frame. If there's distortion, adjust the back focus distance as shown until your stars are as round as possible.

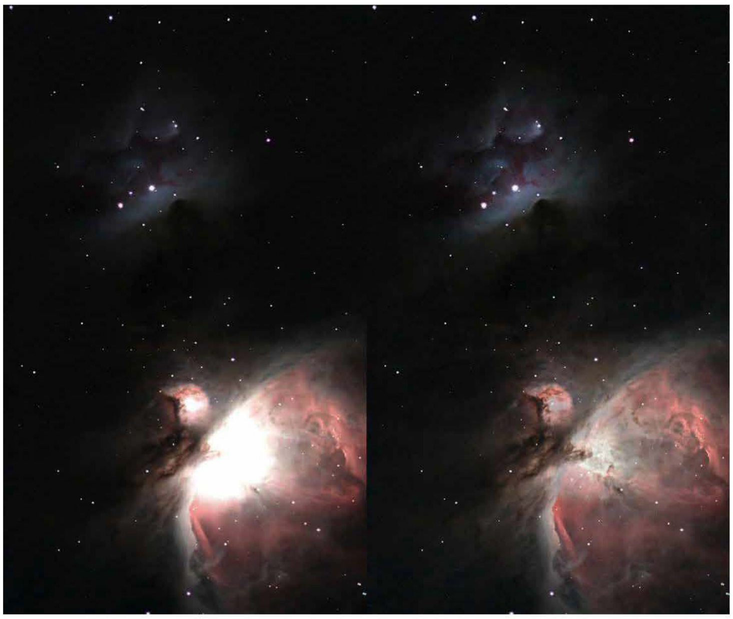
Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Preserving the Orion Nebula's core

It's too easy to burn out the core when imaging M42. We explain an easy way to avoid it

Along with the Andromeda Galaxy, the Orion Nebula (M42) is probably the most photographed deep-sky object. And for good reason – it's large, bright, highly detailed and very colourful. But its brilliance can work against you, as many smart scope owners have discovered. It's all too easy to burn out the core, leading to a nebula that looks beautiful around the outside but a pure-white mess in the middle. This month, we're looking at a simple method for restoring the core to produce a high-dynamic-range (HDR) image of the nebula similar (albeit more colourful) to what you'd see through the eyepiece.



▲ **Smart scopes have a tendency to burn out M42's core (left), but this can be addressed by using a simple technique involving layer masking**

Let's first discuss why the core burns out. Take a photograph of the nebula exposed for the core and it'll look wonderfully detailed. However, much of the intricacy and colour of the surrounding area will be lost in darkness. No problem: simply increase the exposure to bring them back. Now you have M42's beautiful surroundings restored in all their glory… but the main nebula core looks burnt out.

There will be a middle ground where the core is close to, but just below, being overexposed. Here there may well be a fair bit of detail in the surrounding regions too, but they will fade into underexposure, something that will be revealed when final processing takes place, the results looking less than perfect.

There is a better way. First, take exposures optimised for the core, completely disregarding the need to capture fine detail adjacent to this region. This can be hard to do as it just feels wrong. There's all that wonderful detail which is relatively easy to capture and you're simply ignoring it! However, stay strong and just capture the core. Once you've done this, flip your sensibilities around and try for the fainter regions, choosing exposures that will burn out the core. Again, it may feel wrong, but stick with it.

If you own a smart scope, you may be wondering how this applies to you. Smart scopes work by taking short exposures and live-stacking them. If you're relying on the output of your device, the key is to limit the number of live-stacked exposures, stopping when the core is correctly exposed. Then do a second capture letting the smart scope do its thing as long as necessary for the outer regions. Most smart scopes allow you access to the raw files, normally in FITS format. If you can do this and are versed in rudimentary image processing, you can stack the results yourself but you should process two versions, one for the core and one for the outer regions.

What you're aiming for here is at least two images that you can manually combine to create an HDR result that shows the core and outer regions properly exposed in a single shot. If you get adept at the process, you could also use more than two steps to further refine the result.

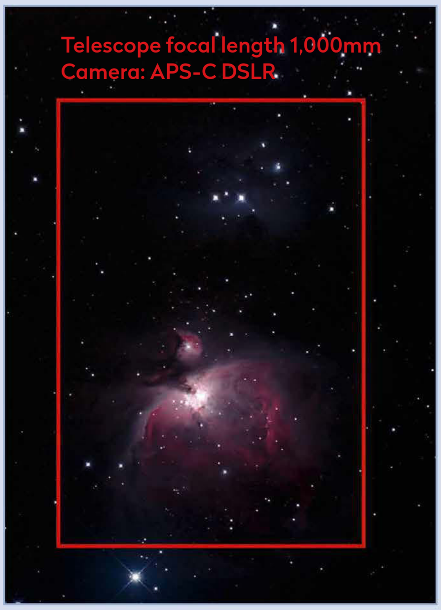
Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

ALL PICTURES: PETE LAWRENCE

Equipment: Smart scope or a camera fitted to an equatorially mounted and driven telescope

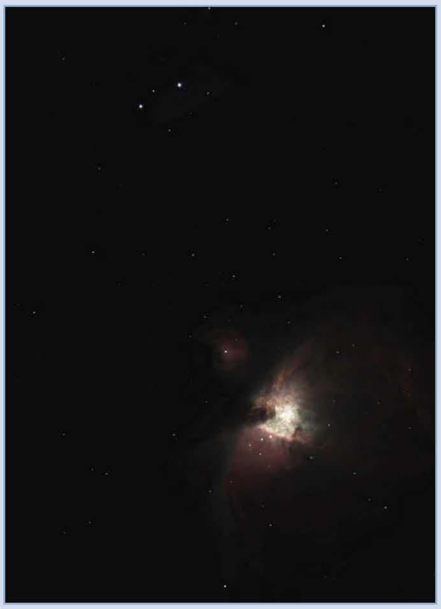
✉ **Send your images to:**
gallery@skyatnightmagazine.com

Step by step



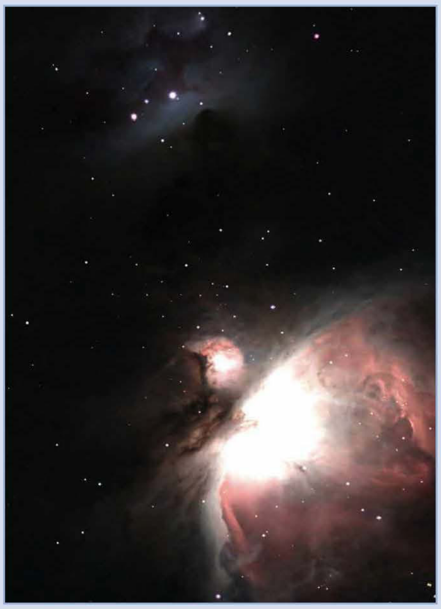
STEP 1

Choose a setup that captures a decent amount of M42 and objects adjacent to it (the Running Man Nebula makes a great addition). Framing and orientation are a personal choice, but a shot with space to allow the nebula to breathe creates a better result. For smart scopes that don't do mosaics, the framing and orientation are dictated by the scope's design and time of night you're doing the imaging.



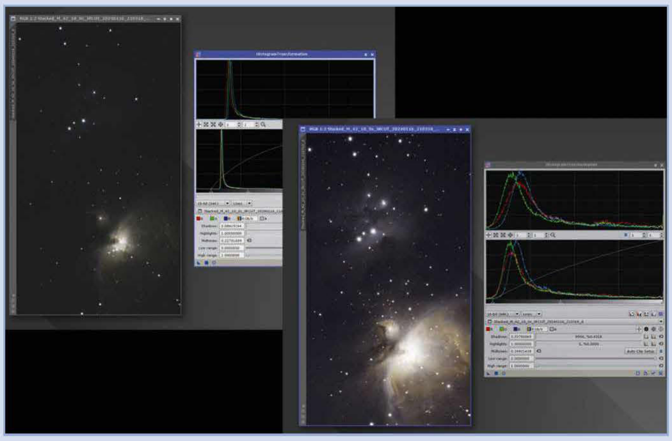
STEP 2

Set the exposure time to avoid burning out the core. It can appear bright, but you don't want areas of pure white. Completely disregard the outer regions of the nebula at this step; they really aren't important. If using a smart scope and intending to use the internally generated image, stop the capture when the core region begins to appear bright.



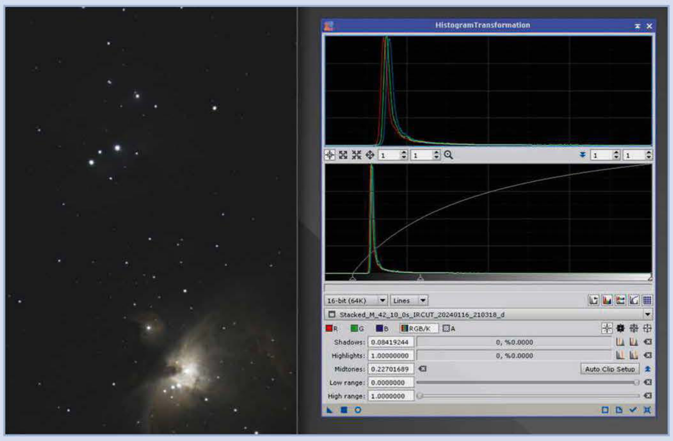
STEP 3

Once you have a correctly exposed core from Step 2, it's time to concentrate on the outer regions. Increase your exposure or ISO settings to bring these out best. Don't worry that the core becomes washed out. If you're using a smart scope, this will simply be a regular session on the nebula, capturing at least 30 minutes' worth of image data.



STEP 4

If you're using a smart scope and want to process its FITS files yourself, download them and use your favourite processing software to generate a result from the image stack. When you stretch the data, create one version favouring the core and another for the outer regions. Save them as separate images.



Stacked_M_42_10_0s_IRCUT_20240116_210318_d

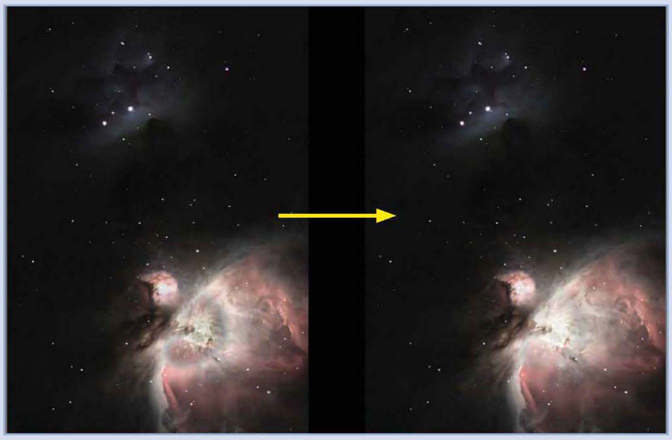
Shadows: 0.08419244 0, %0.0000

Highlights: 1.00000000 0, %0.0000

Midtones: 0.22701689

Low range: 0.0000000

High range: 1.0000000



STEP 5

You should now have two images: the core and the outer regions. Using a layer-based image editor, copy and paste each result into a separate layer in the same image. Put the outer region shot above the core image. Use the magic wand tool to select the white core in the upper layer. Copy and paste as a layer mask.

STEP 6

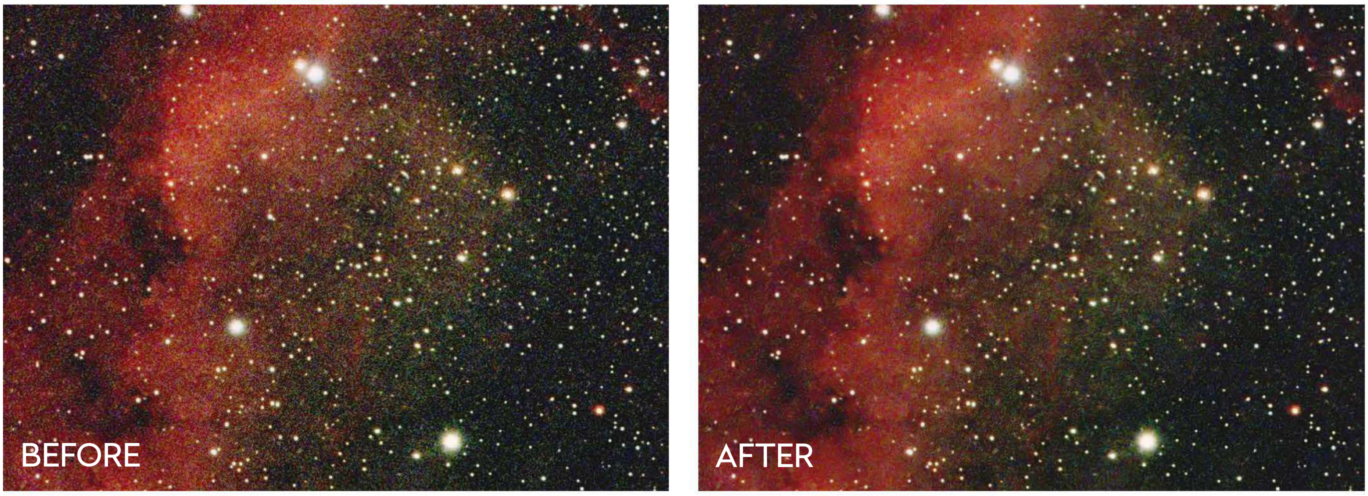
Select the layer mask and blur the image to soften the edges. You'll see that the hole in the upper image begins to blend with the core image below. When you're happy with the edge blending, consider a gentle curve tweak of the lower core image so its appearance is more suited to the overall look.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

How to reduce image noise using Affinity Photo

Banish grainy artefacts and enhance details using a simple denoising tool



▲ Left: a zoomed-in portion of Dave's image of the Heart Nebula from 20 stacked 200-second frames, showing lots of noise and grain. Right: the same region after using Affinity Photo's Denoise tool to reduce the graininess and reveal fine details in the nebula

There are many obstacles to overcome when we process deep-sky images. One key challenge is the noise that creeps in when we stretch the data from these faint objects and prevents us from unveiling delicate details.

Even everyday images taken using a smartphone or DSLR have noise. The big difference is that during the daytime there is a lot of light available; with astrophotography, there's usually very little light, meaning most of the data in our images is down towards the 'black end' of the histogram, where it's nestled within most of the noise.

As the image is stretched, so is the noise, which becomes more visible. While this can be reduced by collecting more data – generally, the more images that are stacked together, the less visible the noise becomes – most of us still end up with some noise in our images that we need to reduce. Here I'll show you how to achieve this in Affinity Photo 2, which has a great 'Denoise' tool that can be used not only for deep-sky but also Moon and planet images.

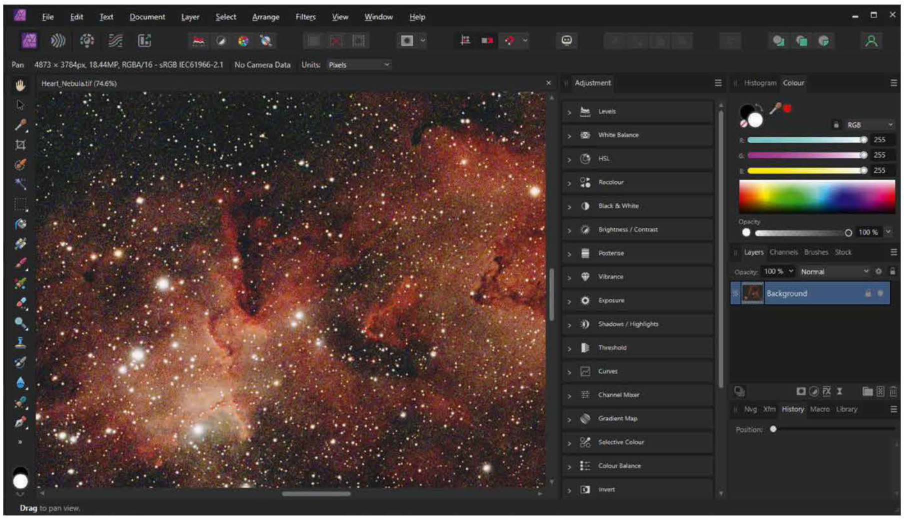
My one-shot colour image of the Heart Nebula (above, left) was the result of 20x 200-second subs. I had already stacked and stretched these using Affinity Photo's 'Curves', 'Vibrance' and 'Levels' tools to increase the contrast and saturation. Making these adjustments brought out unwanted background noise, preventing me from further stretching my data and unveiling other details. This was more obvious when zooming into the image in the areas that had both bright and dark areas, where noise is easily seen (see Screenshot 1).

Let's get started

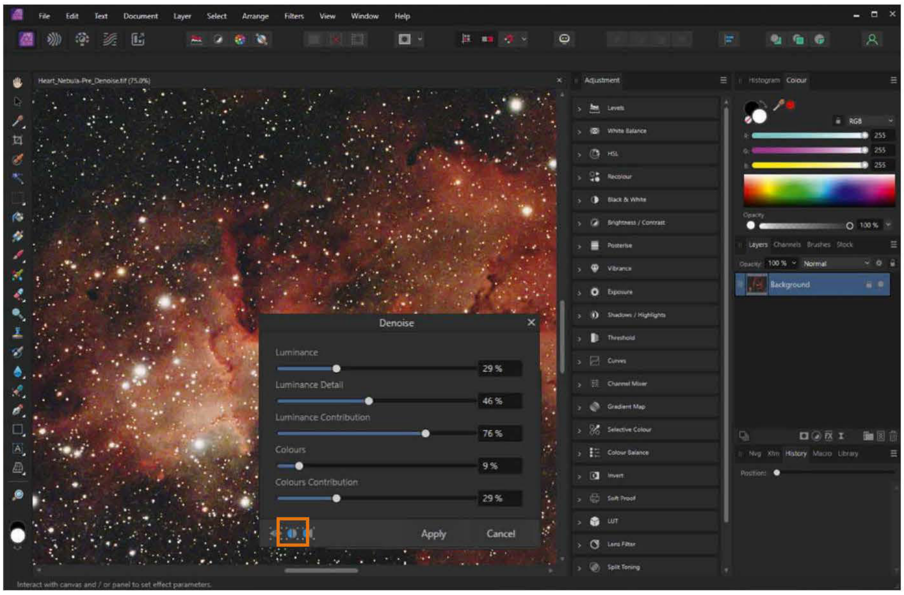
Open your image in Affinity Photo. To access the Denoise tool, click Filters › Noise › Denoise. When first opened, the tool will apply default denoise settings to your image. Five adjustments can be made from within the tool: Luminance, Luminance Detail, Luminance Contribution, Colours and Colours Contribution. As the names suggest, the top three sliders reduce noise resulting from luminance, while the bottom two work on colour noise.

It can be difficult to see the effect of using Denoise on your image, so to get a better idea click 'Split View' at the bottom-left (highlighted, Screenshot 2).

ALL PICTURES: DAVE EAGLE

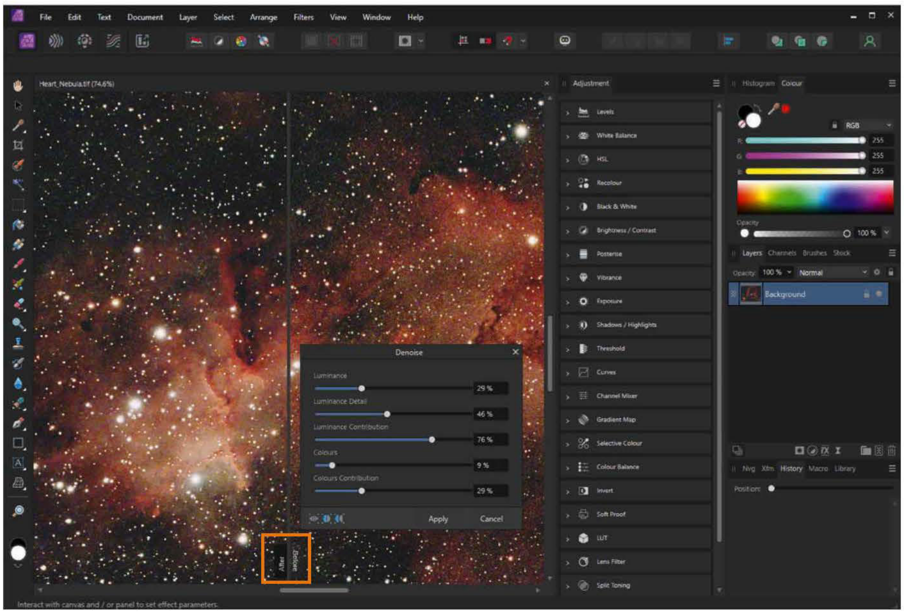

File
Edit
Text
Document
Layer
Select
Arrange
Filters
View
Window
Help
Pan 4873 × 3784px, 18.44MP, RGBA/16 - sRGB IEC61966-2.1 No Camera Data Units: Pixels
Heart_Nebula.tif (74.6%)
Adjustment
Levels
White Balance
HSL
Recolour
Black & White
Brightness / Contrast
Posterise
Vibrance
Exposure
Shadows / Highlights
Threshold
Curves
Channel Mixer
Gradient Map
Selective Colour
Colour Balance
Invert
Histogram
Colour
RGB
Opacity
Layers
Channels
Brushes
Stock
Normal
Background
Nvg
Xfm
History
Macro
Library
Position:
Drag to pan view.

▲ Screenshot 1: open your image in Affinity Photo. Even after stacking multiple frames, you may see noise – particularly in areas with both bright and dark details – that only worsens as you stretch the data. Click Filters › Noise › Denoise to open the denoise tool


Heart_Nebula-Pre_Denoise.tif (75.0%)
Denoise
Apply
Cancel
Interact with canvas and / or panel to set effect parameters.

Luminance 29 %
Luminance Detail 46 %
Luminance Contribution 76 %
Colours 9 %
Colours Contribution 29 %

▲ Screenshot 2: the effect of the Denoise tool can be subtle, so use the Split View button at the bottom-left to show a live before and after view as you make your adjustments


Heart_Nebula.tif (74.6%)
Denoise
After
Before
Apply
Cancel
Interact with canvas and / or panel to set effect parameters.

Luminance 29 %
Luminance Detail 46 %
Luminance Contribution 76 %
Colours 9 %
Colours Contribution 29 %

▲ Screenshot 3: it's tempting to overdo it, but keep changes small. Carefully watch the effect on the left-hand side of the screen, regularly zooming out to check the overall image

3 QUICK TIPS

1. The Denoise 'Mirror View' can also be used to inspect the denoise preview side by side.

2. In Settings › Tools, set your mouse wheel to enable it to zoom in and out of images.

3. Be very careful adjusting settings, as applying too much denoise can blur any fine details.

A dividing line, splitting your view of the image into two, will appear in the middle of the window, with an 'After' and 'Before' tab on either side (see Screenshot 3). The right-hand side shows the original image before applying Denoise. The left-hand side shows the result of applying Denoise via the sliders. To get a much better idea of what the Denoise tool is doing to your image, grab the line with your mouse and move it to the left or right to reveal less or more of each side of the image.

You may decide to either accept the default settings provided by Affinity Photo 2 or manually adjust the sliders – moving them to the right increases the amount of denoise applied.

Like many image-processing techniques, you'll need to be very careful not to overdo things. It's a fine balancing act of reducing noise to an acceptable level without detrimentally affecting the image. When too much denoise is applied, fine details can start to blur.

Make your adjustments and keep moving the split screen from left to right across the image to see the effect of the changes. Zoom in and out of the image using the magnifying glass tool (bottom-left) to see how each change affects the overall view while scanning the Split View across the image. Taking a combination of wide and close-up views of the image will give you a good idea of how each adjustment affects the image at all levels.

Once you're happy with the result, click 'Apply' and close the Denoise tool (highlighted, Screenshot 3). My final image (opposite, right) has much less noise, allowing finer details to shine through.

Dave Eagle is an astronomer, astrophotographer, planetarium operator and writer

Your best photos submitted to the magazine this month

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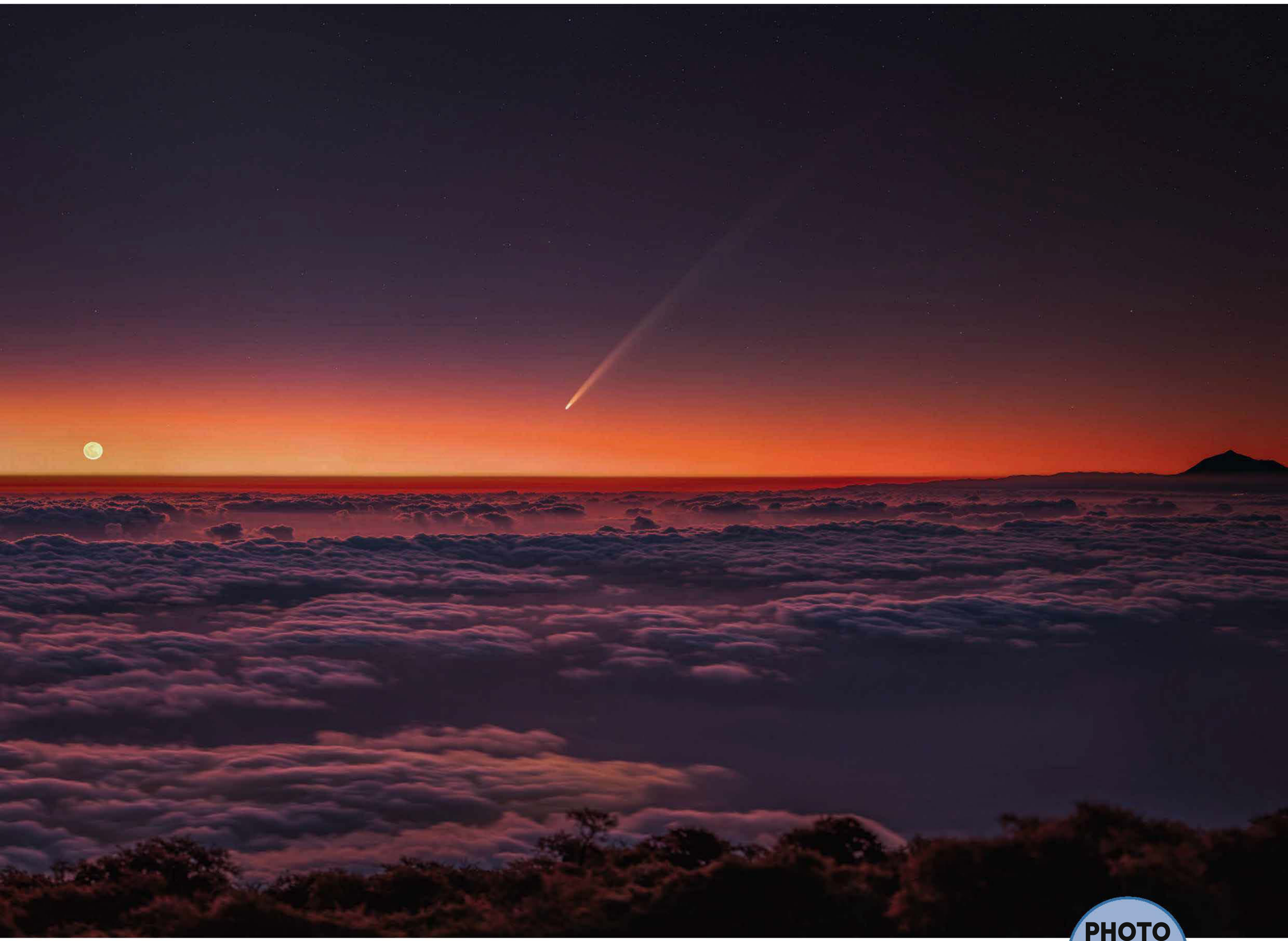


PHOTO OF THE MONTH

△ The Moon, comet C/2023 A3 and Mount Teide

Gergely Tóth, Caldera de Taburiente, Canary Islands, Spain, 1 October 2024

Gergely says: "Comet C/2023 A3 is framed here by the Moon and the Mount Teide volcano, creating a unique natural alliance in the sky."

Equipment: Sony a7 IIIa camera, Samyang 135mm lens, Benro Polaris tripod
Exposure: Sky ISO 640 f/1.8, 8x 8"; foreground ISO 640 f/1.8, 8x 4"
Software: Lightroom, PTGui, Photoshop

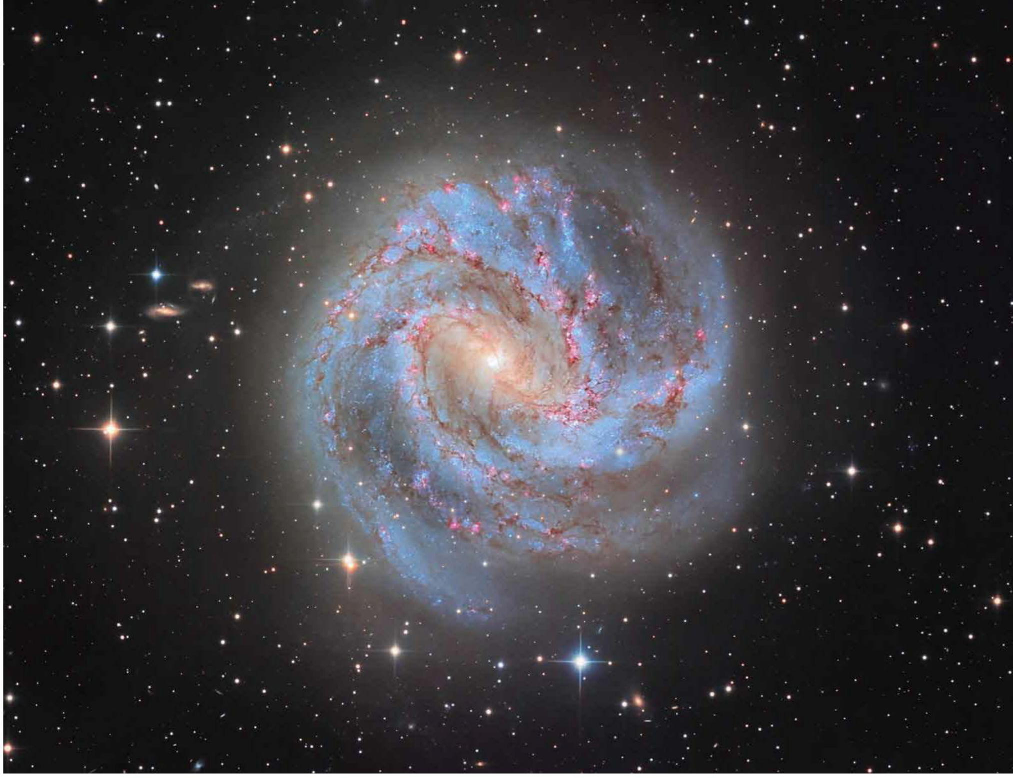
Gergely's top tips: "When photographing comets, be ready to change your exposure settings to deal with rapidly changing light conditions or you might burn out the highlights or end up with an underexposed image. I suggest using planetarium apps like Sky Guide – that's how I found out the Moon would rise just five minutes after the comet and align perfectly with the volcano."

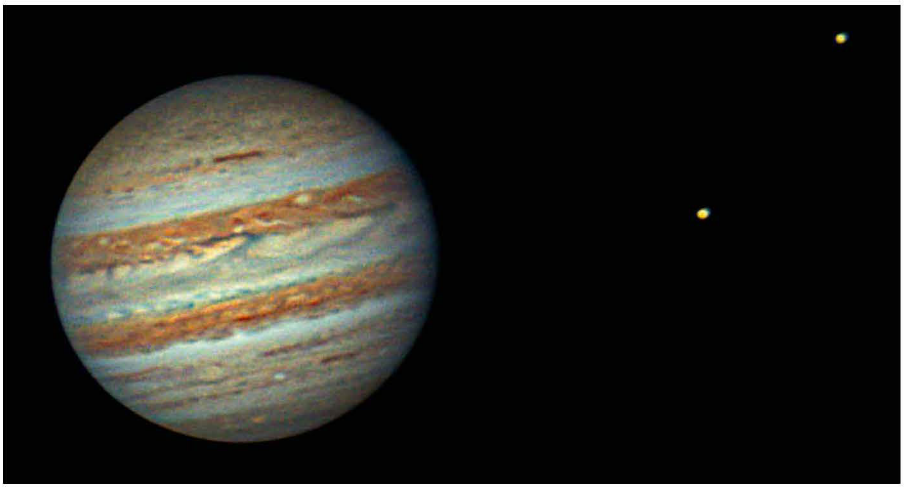
The Southern Pinwheel Galaxy ▷

Massimo Di Fusco and Adriano Anfuso, captured remotely via Telescope Live, Rio Hurtado, Chile, 20 August 2024

Massimo says: "This picture is a collaboration with my friend Adriano. He captured the raw data, which I then processed in PixInsight and Photoshop."

Equipment: FLI PL 9000 camera, PlaneWave CDK24 astrograph, Mathis Instruments MI-1000/1250 mount
Exposure: RGB 15x 300" each, L 18x 600"
Software: PixInsight, Photoshop





◁ Jupiter, Io and Europa

John Chumack, Dayton, Ohio, USA, 8 October 2024

John says: "The key to good planetary imaging is shooting while the planet is high in the sky and the atmosphere is very stable, and getting precise focus."

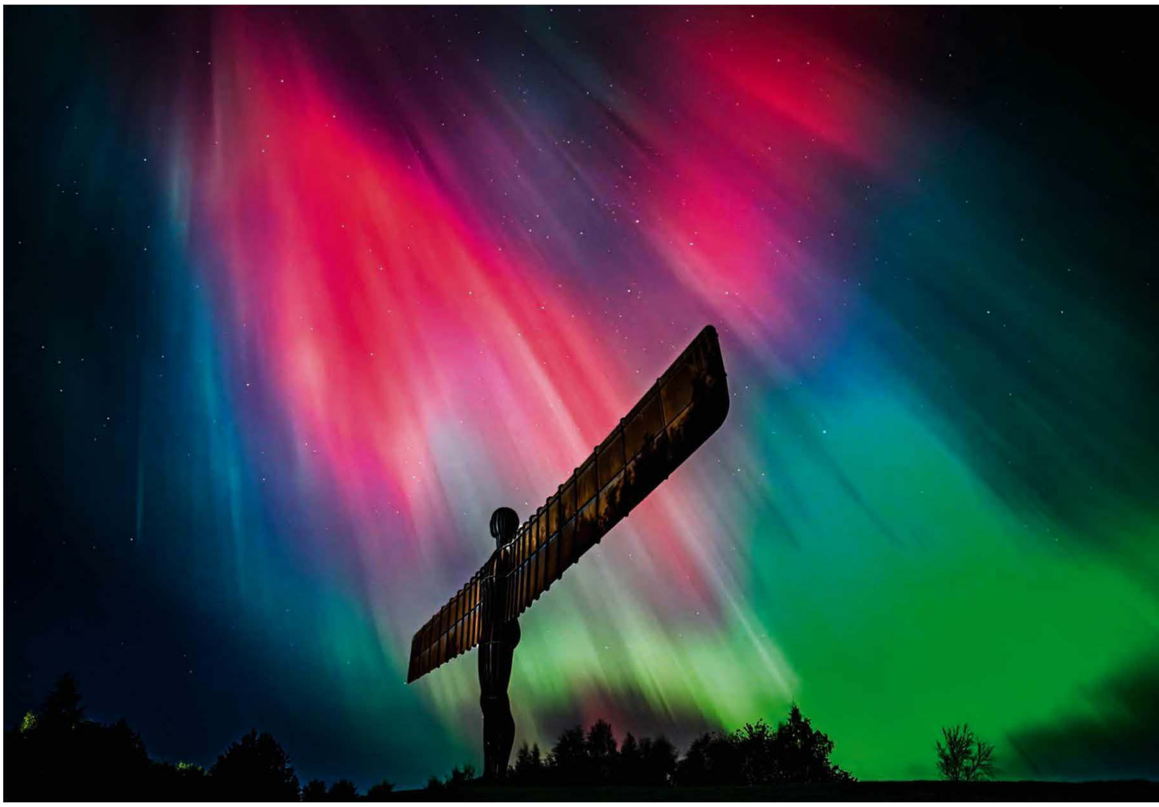
Equipment: QHYCCD QHY5III462 M/C camera, Celestron C11 Schmidt–Cassegrain, Software Bisque Paramount MYT mount
Exposure: Best 3,100 of 7,300 video frames, 6ms exposure **Software:** AstroSurface, RegiStax, Adobe Camera Raw

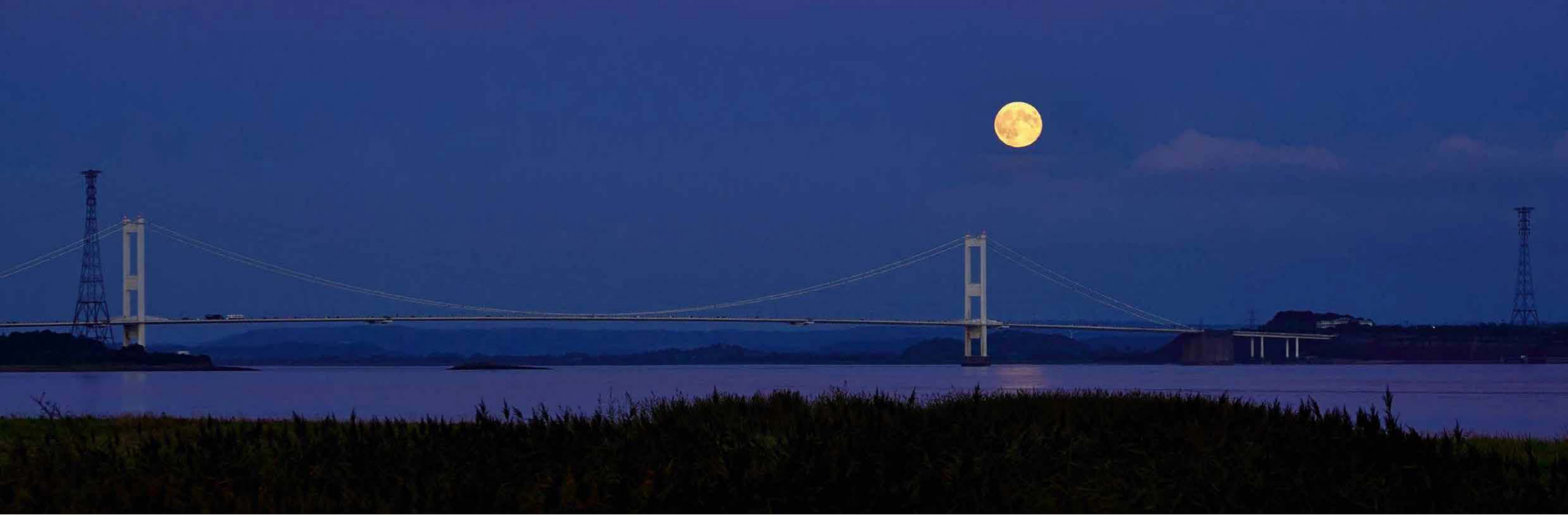
Aurora borealis ▷

Andrew Morkot, Gateshead, Tyne and Wear, 11 October 2024

Andrew says: "The Angel of the North symbolises the history and people of this area, and living five minutes away I wanted to capture this rare aurora above it, using a wide-angle lens to capture its scale."

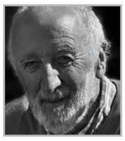
Equipment: Canon EOS R5 camera, Samyang 14mm lens, Manfrotto 190CX3 tripod
Exposure: ISO 800 f/2.8, 4"
Software: Lightroom, Photoshop, Topaz DeNoise AI





△ Supermoon over the Severn Bridge

Tom Roberts, Portskewett, Monmouthshire, 17 October 2024



Tom says: "Sadly, thick cloud prevented any 'Moon illusion' captures – by the time the Moon came into view, it was already higher than the tops of the bridge's pillars."

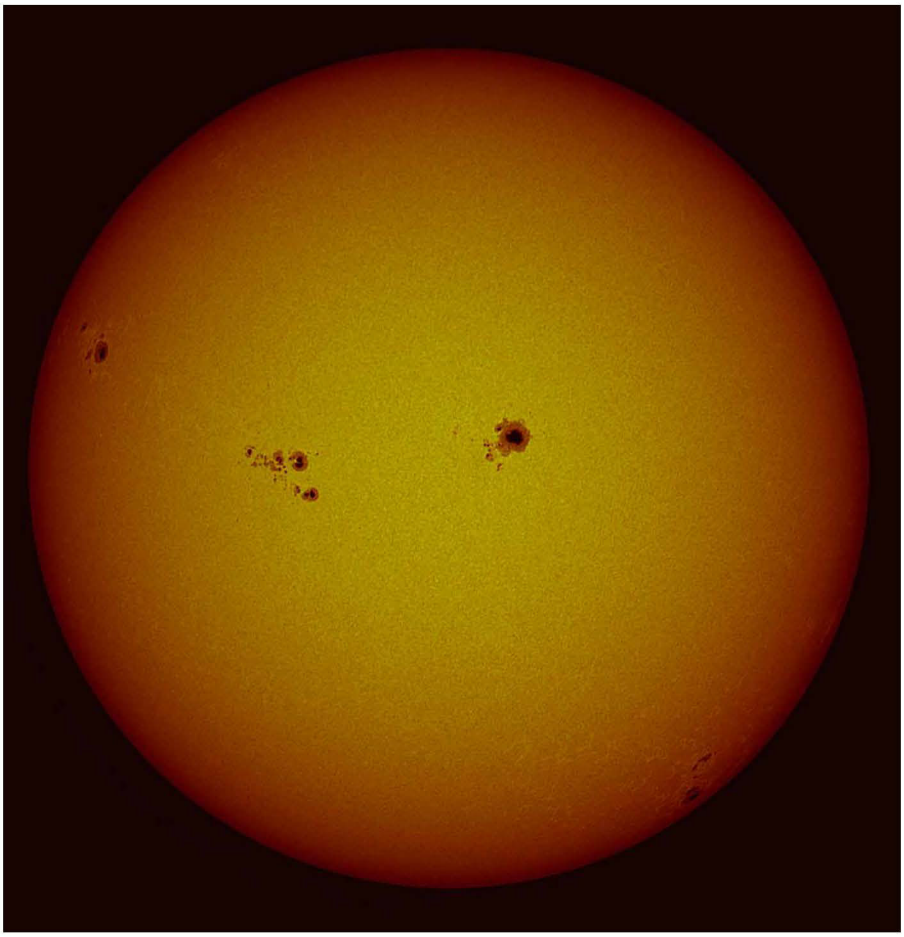
Equipment: Sony RX10 IV camera, Sony 24–600mm lens, Manfrotto 055XPRO3 tripod
Exposure: ISO 100 f/4.0, 1/20'
Software: Photoshop Elements

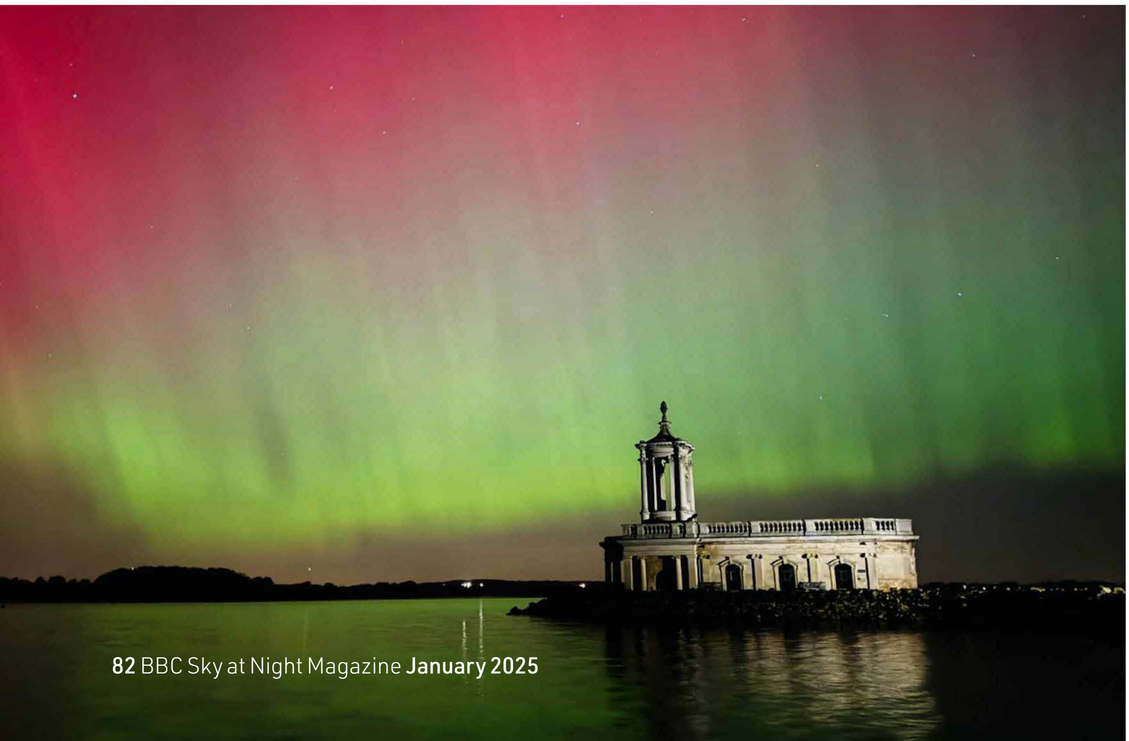
The Sun ▷

Paul Gordon, Hullbridge, Essex, 8 October 2024

Paul says: "I wanted to try imaging sunspots on the Sun's surface, so I set my equipment up on the west of my property to get a clear view of the setting Sun."

Equipment: ZWO ASI533MC camera, Vixen ED103S refractor, Sky-Watcher HEQ5 Pro mount
Exposure: Best of 100 video frames
Software: RegiStax, Photoshop





◁ Aurora borealis

Joanne Popple, Rutland Water, Rutland, 11 October 2024

Joanne says: "Being a novice, I'm pleased with how this image turned out – especially as the location, Normanton Church, is where my husband and I got married in 2015."

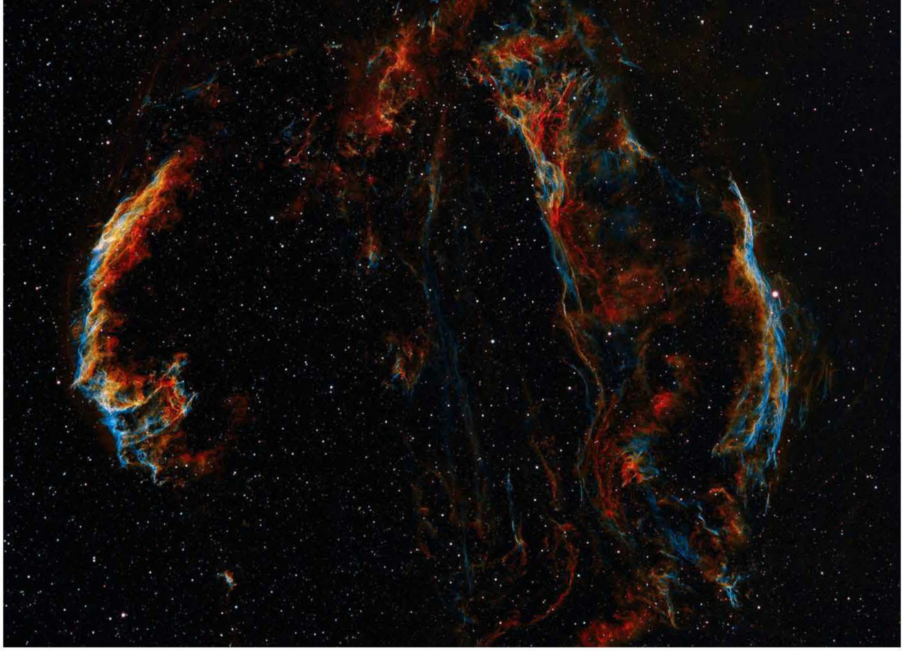
Equipment: iPhone 15 Pro
Exposure: 3"

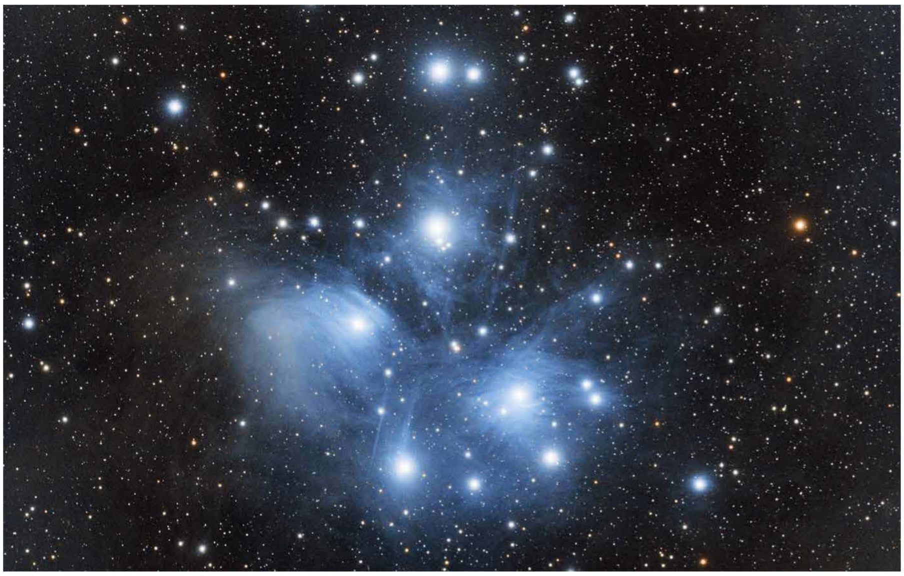
The Veil Nebula ▷

Andrei Pleskatsevich, Minsk, Belarus, 17 October 2024

Andrei says: "The Veil Nebula is one of my favourite targets. Last year I processed it in HOO, so this year I've tried to emulate an SHO palette with my colour camera."

Equipment: ToupTek ATR3C571 camera, SharpStar 76EDPH refractor, iOptron GEM28 mount **Exposure:** 40x 600" **Software:** Deep Sky Stacker, Photoshop





◁ The Pleiades

Mike Read, Corsley, Wiltshire, 3 October 2024

Mike says: "I'm fascinated by the Seven Sisters. I love capturing the dust clouds and aiming to spot that faint 17th-magnitude galaxy nearby. When the first combined stretch reveals the dust – that's my happy place."

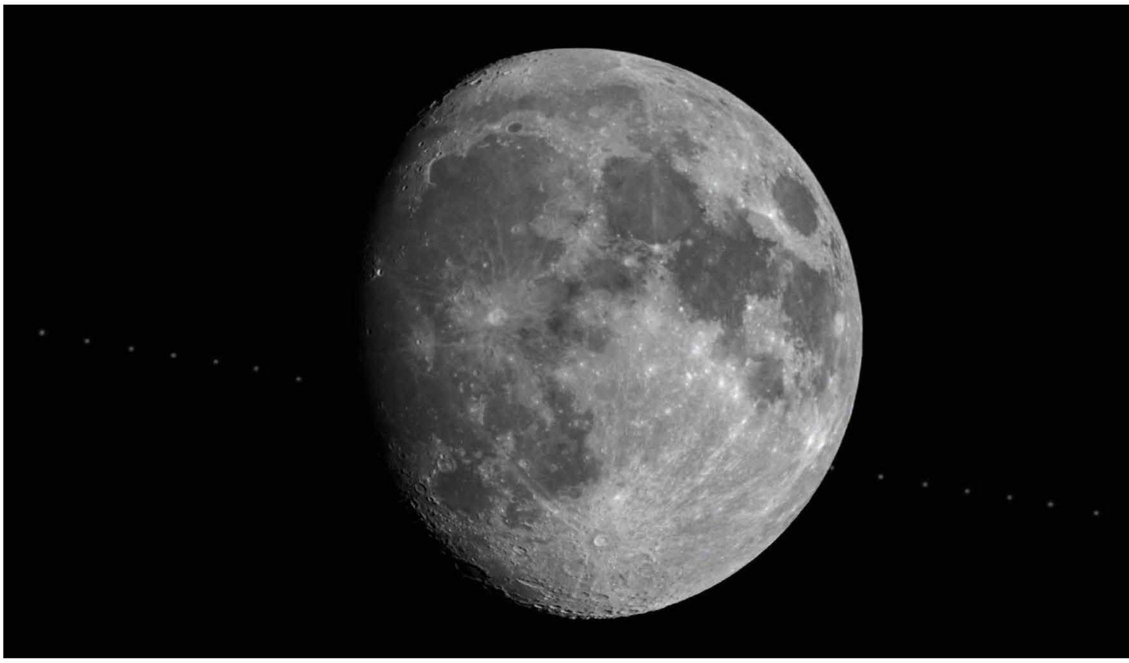
Equipment: QHYCCD QHY268M camera, Sky-Watcher Esprit 100 ED refractor, Sky-Watcher EQ6-R mount **Exposure:** RGB 10x 90" each, L 10x 180" **Software:** PixInsight

Lunar occultation of Saturn ▷

Soumyadeep Mukherjee, Kolkata, India, 15 October 2024

Soumyadeep says: "The disappearance view of this occultation was stunning and visible to the naked eye – though sadly for my location the reappearance was obscured by very poor seeing."

Equipment: Nikon D5600 camera, Sigma 150–600mm lens, iOptron Sky-Guider Pro mount **Exposure:** Moon and Saturn ISO 1600 f/6.3, 1/100"; lunar disc ISO 1600 f/6.3, 1/125" **Software:** PIPP, AutoStakkert!, Adobe Camera Raw, Photoshop



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QSI
Panoro
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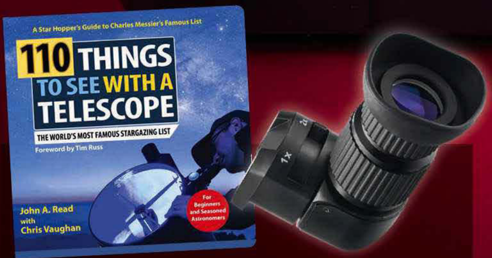
86

Does QSI's full-frame mono camera dazzle enough to justify its deluxe price tag? Read our review to find out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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★☆ Very good
★★★☆☆ Good ★★☆☆☆ Average ★☆☆☆☆ Poor/avoid

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QSI 760 full-format mono CMOS imaging camera

Geared towards specialists, this full-frame powerhouse gives sensational results

WORDS: CHRIS GRIMMER

A full-frame astronomy camera is often at the top of many astrophotographers' wish lists, so when QSI released the QSI 760 – a full-frame mono camera featuring the latest CMOS sensor – we were keen to check it out.

Arriving in a large sturdy box, the first thing that struck us was the very impressive case the camera is housed in. Opening this, we found the sizeable camera, with filter wheel already attached, nestled securely alongside a power supply, USB cable and 2-inch nosepiece. Screws were also supplied for attaching unmounted filters.

Heading to the QSI website, the instruction manual was easy to find and provided clear information on how to set the QSI 760 up. There were also detailed drawings and measurements, allowing us to precisely work out the optimal spacing for our field flattener. To ensure that getting up and running is as simple as possible, QSI has bundled all its camera drivers into one easy install file, ensuring the correct one is always installed. There's also a SGPro software subscription included (a nice addition, we felt), which is downloaded separately.

The front plate of the filter wheel has a female M54 thread for either connecting the supplied 2-inch nosepiece or for directly attaching to your telescope or accessories. Given the large-format CMOS sensor within this camera, for many users a field flattener will be a must-have accessory. Using a separate thread adaptor (M54 to T2 in this case) and spacers, we were easily able to attach our flattener. With the software and drivers installed, we proceeded to attach the camera to our telescope and connect the included power supply and USB 3.0 cable.

Loading up SGPro, we were pleased to see that the camera was instantly recognised by the image-sequencing software. Connecting the QSI 760 loaded a second window that gave us the option to change the gain setting. QSI has developed three pre-selectable options: high, medium and low, plus a self-customisable option. For our test, we selected ▶

VITAL STATS

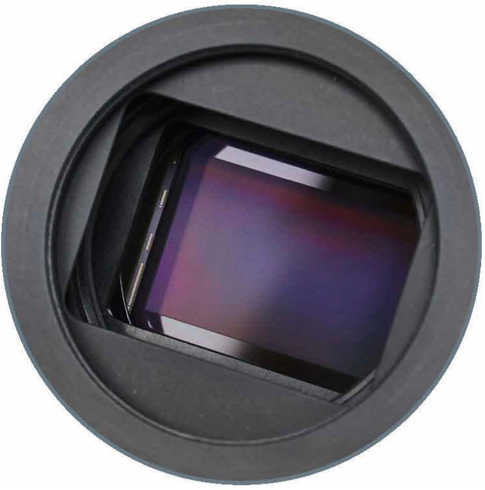
- **Price** £5,873 with five-position filter wheel; £6,058 with seven-position
- **Sensor** Sony IMX455 full-frame mono
- **Resolution** 9,576 x 6,380
- **Exposure range** 1ms–24 hours
- **Connectivity** USB 3.0
- **Size** 190 x 200 x 140mm with integrated filter wheel
- **Weight** 1.9kg
- **Supplier** First Light Optics
- **Email** questions@firstlightoptics.com
- **www.** firstlightoptics.com

First-rate sensor

The QSI 760 features the latest Sony IMX455 mono CMOS sensor, which is recognised by many as one of the best sensors on the market for astrophotography. This full-frame sensor measures 43.3mm diagonally and offers a massive 9,576 x 6,380-pixel resolution, so will benefit from being paired to a telescope capable of illuminating the entire 44mm to take full advantage and avoid any significant vignette.

Thanks to its backside-illuminated architecture, the Sony IMX455 offers a quantum efficiency (QE) of 90 per cent, which means it can translate 90 per cent of the light it receives into data on the sensor. Comparing this to other high-end CCD cameras that max out at a QE of around 77 per cent firmly positions this camera as a market leader.

Another feature of the sensor is the exceptionally clean images it produces. Examining a stretched five-minute dark frame captured at high gain showed low noise, zero amp glow and no artefacts or banding.



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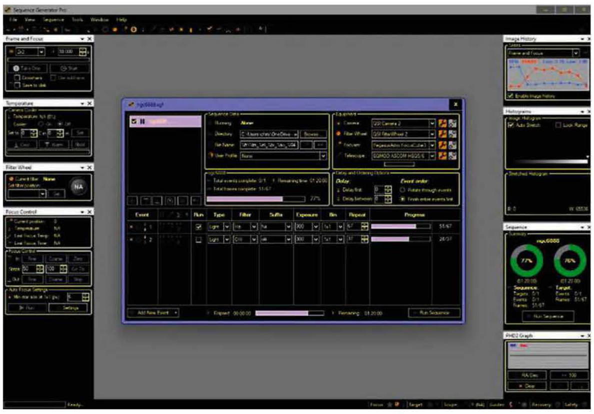
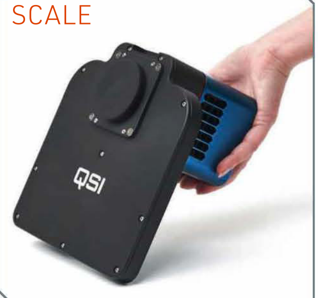
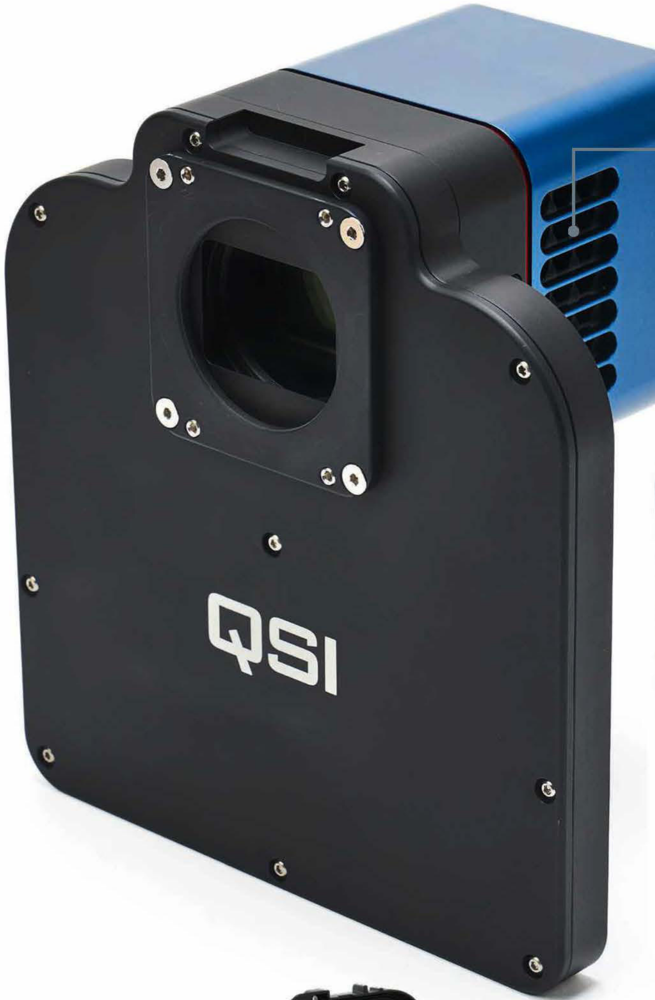


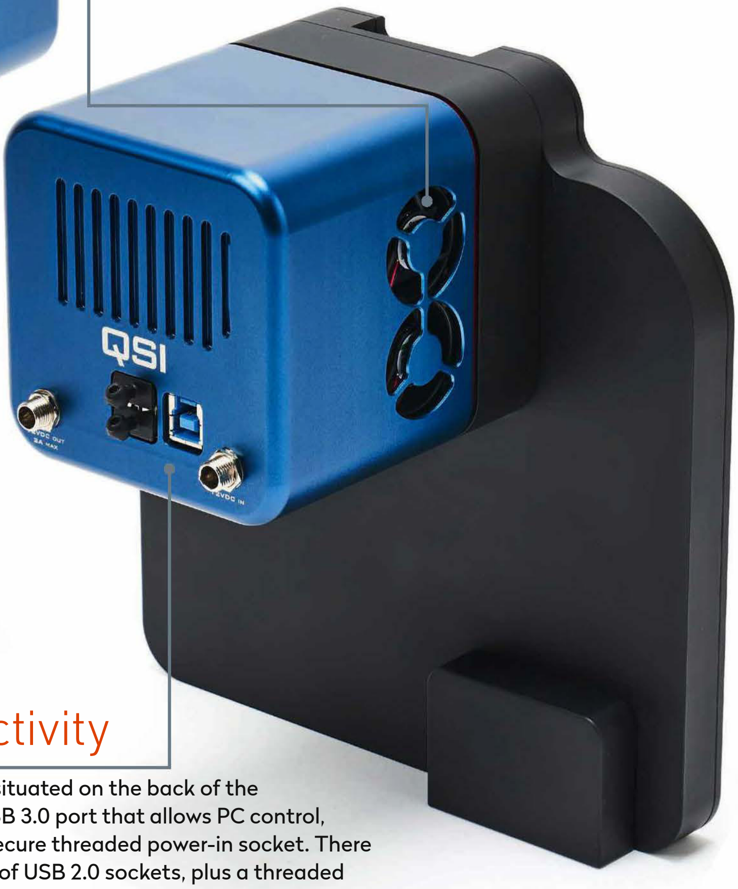
SGPro subscription

All purchases of the QSI 700 include a free full-featured subscription to SGPro. Once installed, you register the software using the camera's serial number and this is then yours to keep without the need to buy an annual subscription. The subscription, however, is locked to QSI cameras only.

SCALE







Cooling

The combination of a two-stage Peltier cooler, fans and large air intake means the QSI 760 can achieve temperatures down to 45°C below ambient. Throughout use and with outside temperatures still in the low double figures, the camera kept a steady –10°C during each imaging session.

Connectivity

Conveniently situated on the back of the camera is a USB 3.0 port that allows PC control, along with a secure threaded power-in socket. There are also a pair of USB 2.0 sockets, plus a threaded 2.5mm 12V power-out socket that allow control and power for ancillary devices, such as guide cameras.

Carry case

Supplied as standard is a robust and well-made hard case. Made from molded durable plastic, it is filled with snug shaped foam to accept the camera with filter wheel attached, along with all its included accessories. This ensures there is no risk of the camera coming to harm while travelling or in storage.

KIT TO ADD

1. QSI off-axis guider
2. Set of 2-inch mounted narrowband filters
3. Set of 2-inch mounted LRGB filters

▶ the high gain setting and connected the rest of our equipment.

We first slewed over to the Elephant's Trunk Nebula which, thanks to the QSI 760's large 43.3mm diagonal sensor and our 478mm focal length refractor, fitted easily into our field of view. With the camera now cooled to –10°C and holding steady, we set up a series of five-minute exposures and started our imaging session. Monitoring the camera closely, we were pleased to see every image captured downloaded quickly and without error. After our three-hour image run with our hydrogen-alpha filter was complete, SGPro seamlessly spun the filter wheel and selected the OIII filter, with a reassuring little click from the filter wheel as it set this next filter into place.

Exquisite details

At the end of the night, once all images had been collected, we removed the camera and were pleased to see that the optical window was free from condensation, even after a solid eight hours of use with the cooler running on an extremely damp autumnal night.

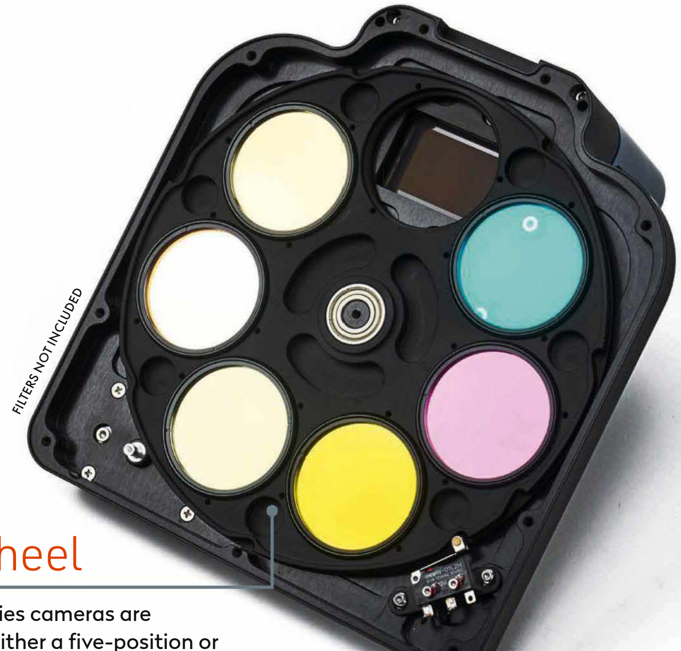
The following morning, we transferred all of our images, including calibration frames, onto our main PC for processing. Once stacked and with calibration frames applied, we were presented with an image rich in detail with very low noise. This allowed us to apply a level of processing and sharpening beyond what we could normally apply, with minimal noise reduction required. We were able to pull out fine details while keeping the image sharp and extremely clear.

Each of the imaging sessions that followed proved to be as flawless, with the data produced just as clean despite the high gain settings used.

The QSI 760 was a real joy to use and the images produced were top-class. This camera is a professional-grade instrument, that was easy to set up and delivered outstanding results time and time again, firmly cementing itself at the top of our astronomy camera wish list.

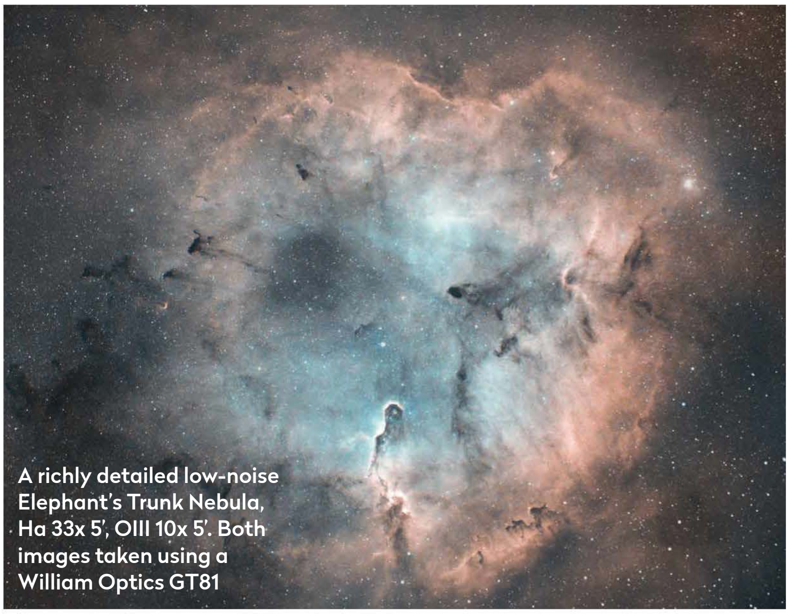
VERDICT

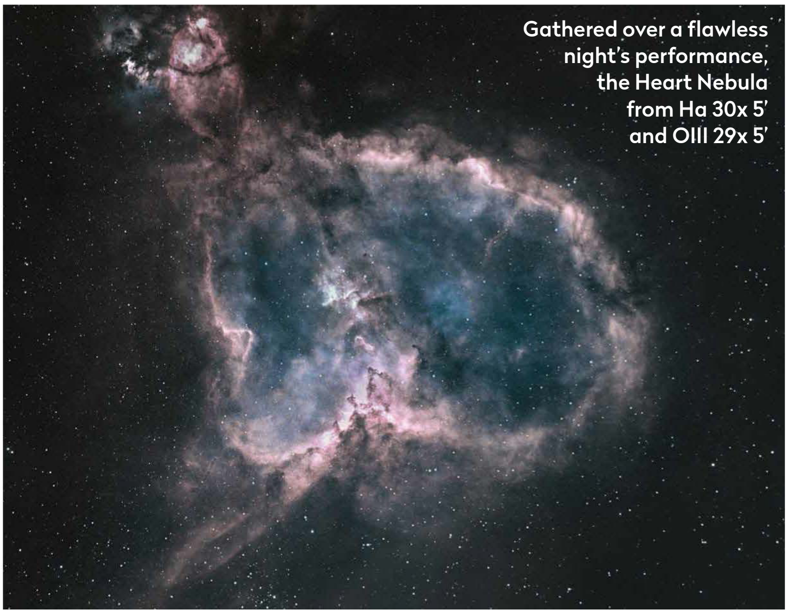
Build & design	★★★★★
Connectivity	★★★★★
Ease of use	★★★★★
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★★



Filter wheel

The QSI 700 series cameras are equipped with either a five-position or seven-position filter wheel that can accommodate 2-inch mounted filters or 50mm unmounted filters. The benefit of having the filter wheel attached is that it reduces the space between the image sensor and filter, minimising filter-induced vignette.


A richly detailed low-noise Elephant's Trunk Nebula, Ha 33x 5', OIII 10x 5'. Both images taken using a William Optics GT81


Gathered over a flawless night's performance, the Heart Nebula from Ha 30x 5' and OIII 29x 5'

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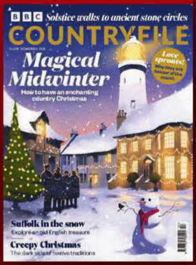
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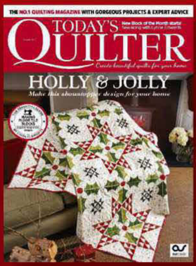
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Our experts review the latest kit

FIRST LIGHT

William Optics Pleiades 68 astrograph

This good-looking compact scope exudes quality and delivers beautiful images

WORDS: TIM JARDINE

VITAL STATS

- **Price** £2,098; £2,197 with guidescope
- **Optics** FPL53 apochromatic septuplet
- **Aperture** 68mm
- **Focal length** 258mm, f/3.8
- **Focuser** Internal rack and pinion
- **Extras** Dovetail bar, tube rings, carry handle, padded case
- **Weight** 3.83kg
- **Supplier** The Widescreen Centre
- **Tel** 01353 776199
- **www.** widescreen-centre.co.uk

William Optics has been a key producer of good-value small refractors in recent times. This latest offering, the Pleiades 68, presents a highly desirable astrograph that ticks so many boxes that, after reviewing it, we were reluctant to send it back!

Everything about this little refractor just exudes attention to detail, from the matching logos on the carry case and telescope, to the quality of the machining. But these aren't as important as its performance, so we were anxious to put it to the test.

With a focal length of 258mm, the 68mm apochromatic objective lens provides a speedy f/3.8 focal ratio. This means a very wide field of view and a telescope designed for use with large, full-frame astronomy cameras. We matched it to our full-frame Atik camera (with large 9μm pixels) using the supplied M54 connector. However, we also required an Askar precision adjustable spacer, which was provided by the Widescreen Centre.

The WIFD focusing system requires camera back focus to be set to exactly 55mm, and we appreciated the detailed and informative manual on the William Optics website to assist with this somewhat fiddly initial set-up process.

With our camera attached, we found that the WIFD format made for a central balance position and it sat securely on its 210mm Vixen-style dovetail bar. A matching 32mm Uniguide scope is available to purchase separately and sits atop the saddle handlebar. Once the initial spacing is all finalised, this is a simple telescope to use and very desirable for travelling astronomy.

Easy to adapt

Almost everything is adjustable on the Pleiades 68, including camera rotation and focuser tension, and there's even a tilt adjuster. Each feature is explained clearly in the manual, with detailed diagrams. One side of the focuser knob contains a thermometer dial. During our review period, the nighttime temperatures ▶

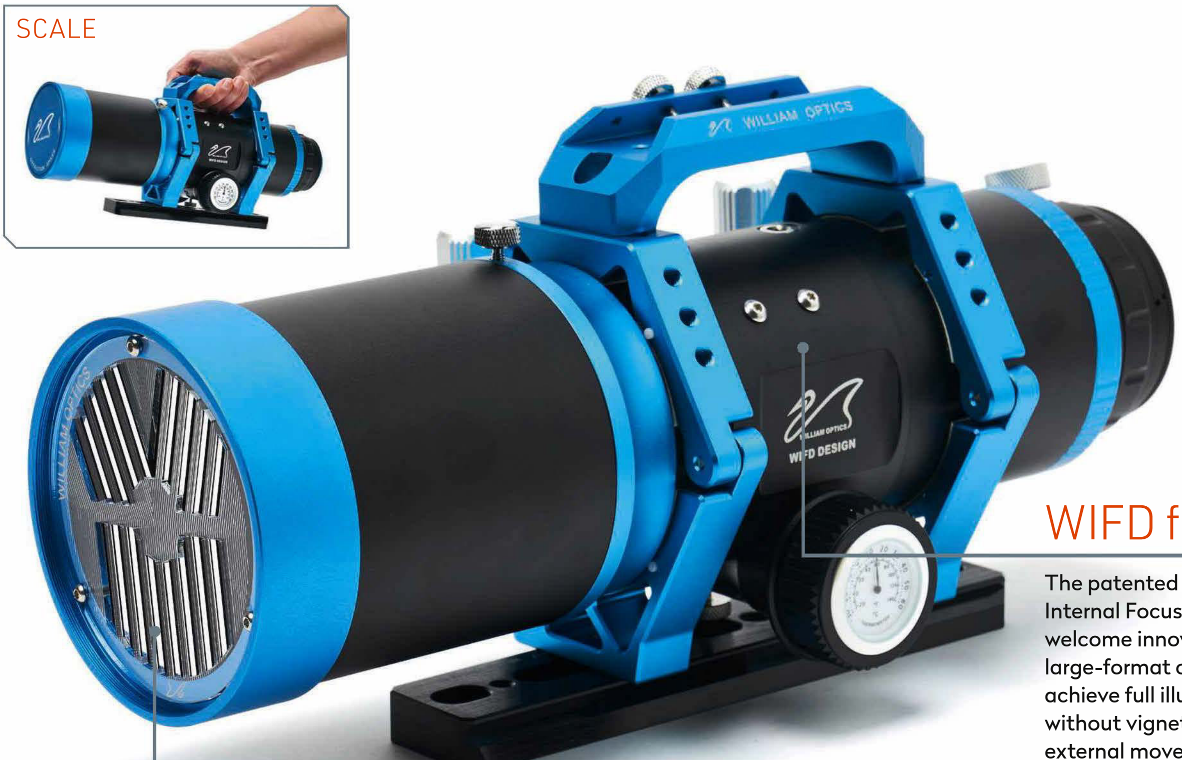
Seven lenses = sharp stars

The Pleiades 68 features an unusual septuplet optical system – no less than seven individual lenses, designed to eliminate the two biggest issues with refractors: chromatic aberration (CA), where the various colours of light tend to come to focus at different points; and field curvature, where stars at the edges of an image deform and stretch. Fast focal ratios often exacerbate these issues. Image results from a full-frame camera, with 36 x 24mm imaging area confirmed that the combination of four rear lenses produces reasonable star shapes right into the corners of the image.

Using parfocal RGB filters in turn, we photographed a star in a central position and then again with the star in each extreme corner, noting that there was no significant shift in colour focus across the image plane. This demonstrated that the three objective lenses bring red, green and blue wavelengths into concentrated points throughout the image, which is crucial for overall sharp focus and essential for one-shot colour cameras.

f=260mm F3.8
Imaging APO
Pleiades 68
SN#23187

ALL PICTURES: @THESHED/PHOTOSTUDIO

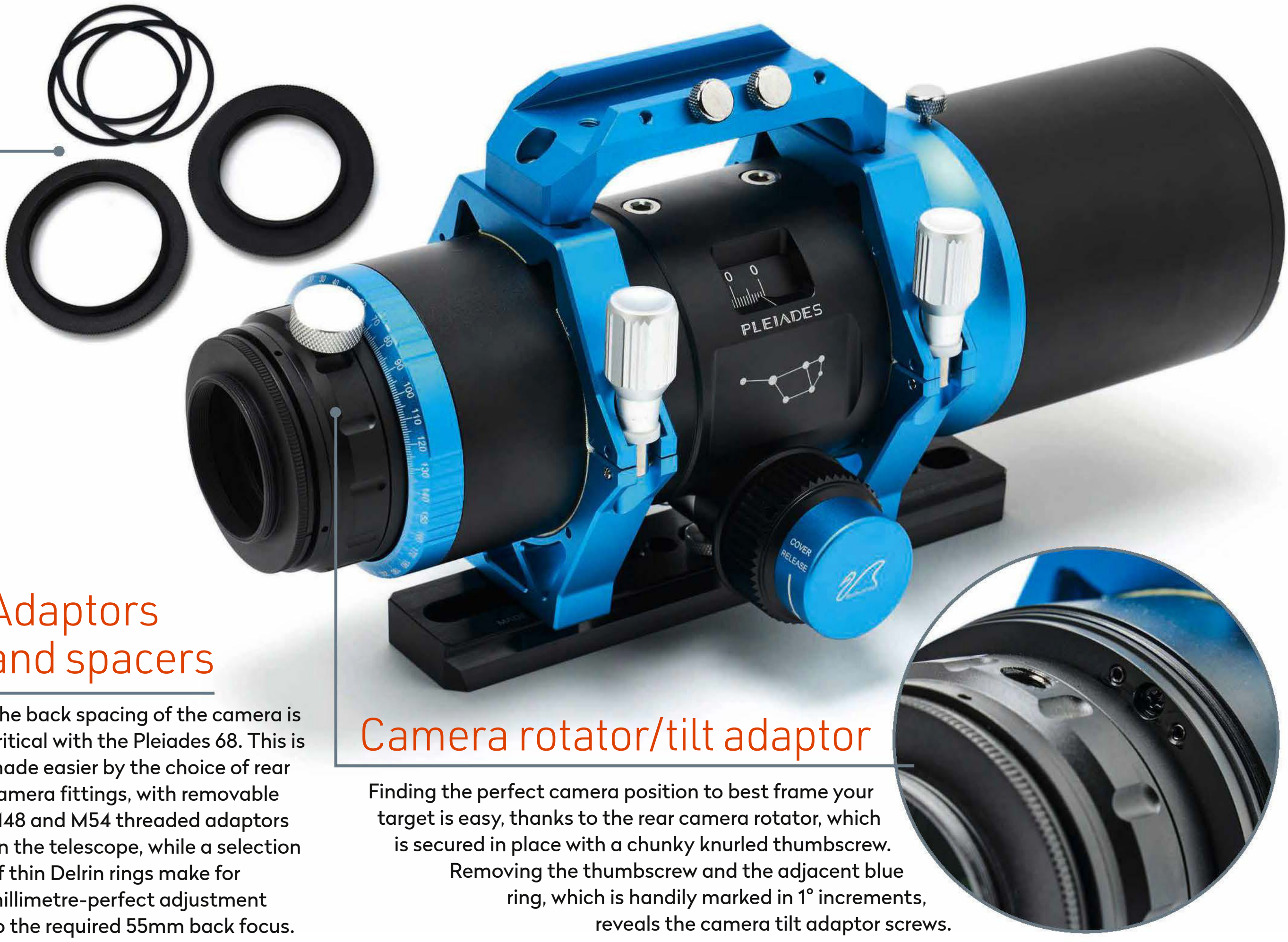


WIFD focuser

The patented William Optics Internal Focus Design is a welcome innovation, enabling large-format cameras to achieve full illumination without vignetting. No external movement is observed during adjustment, as the internal mechanism moves the four rear optical elements forward and back to achieve focus. The silky-smooth twin-speed setup offers outstanding performance.

Bahtinov mask

A favourite feature of ours, the dust cap has a removable plate that unscrews to reveal a Bahtinov mask. This makes precise manual focusing of the telescope a quick and simple task, even though miniscule movements of the fine-focusing knob are required for perfect sharpness at this focal length and f/ ratio.



Adaptors and spacers

The back spacing of the camera is critical with the Pleiades 68. This is made easier by the choice of rear camera fittings, with removable M48 and M54 threaded adaptors on the telescope, while a selection of thin Delrin rings make for millimetre-perfect adjustment to the required 55mm back focus.

Camera rotator/tilt adaptor

Finding the perfect camera position to best frame your target is easy, thanks to the rear camera rotator, which is secured in place with a chunky knurled thumbscrew. Removing the thumbscrew and the adjacent blue ring, which is handily marked in 1° increments, reveals the camera tilt adaptor screws.

Carry case

The branded soft carrying case is stylish, well padded and easily able to protect the telescope during storage or while travelling. It enhances the portability of the Pleiades 68 and makes it a practical size for carry-on aircraft luggage. A handy set of Allen keys is included within the case.

KIT TO ADD

1. William Optics 32mm guidescope

2. Takahashi M54 T-rings

3. Gerd Neumann 'Aurora' 100mm flat panel

▶ were stable, and once we initially focused only miniscule adjustments were necessary throughout our relatively short sessions, dictated by summer nights in the UK.

Reduced darkness notwithstanding, the late summer brought some of the most impressive nebulous regions around the Milky Way, and the Pleiades 68 is made for sucking these huge sky areas in and doing justice to them on camera. To make the best of our clear sky time, we used narrowband hydrogen-alpha (Hα) and oxygen (OIII) filters and applied 2x2 camera binning for some targets to increase light sensitivity.

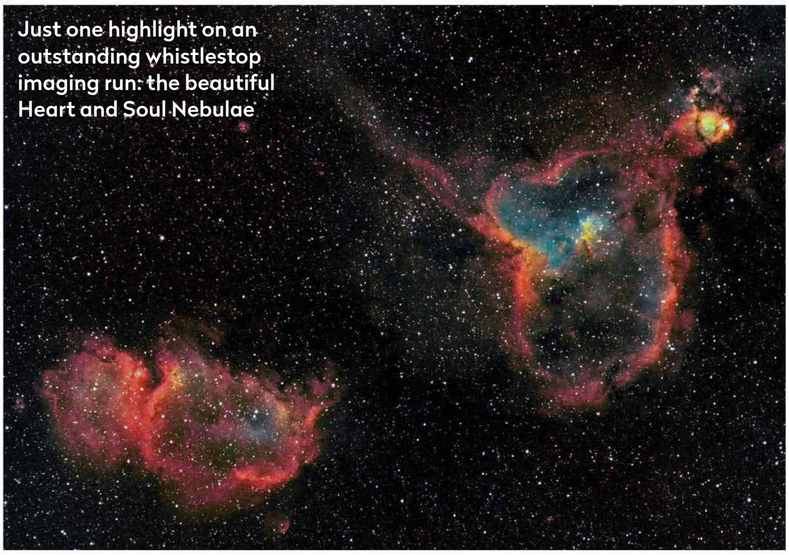
Our first session was on the Elephant's Trunk Nebula. The little scope easily framed the whole scene and when we saw the first image roll in, the Pleiades 68 put a big smile on our face. Star shapes were very good and well handled in the corners.

Small but mighty

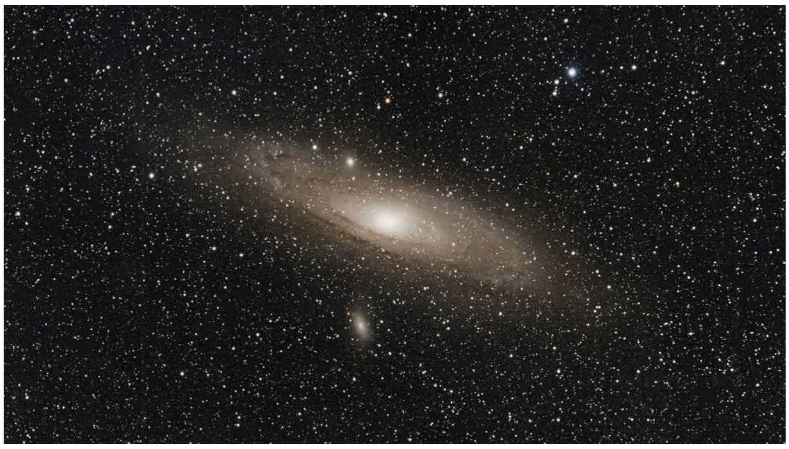
Beautiful image results were achieved every time we had a clear spell: the North America Nebula and Pelican Nebula, the entire Veil Nebula in all its glory, the Heart and Soul Nebulae in Cassiopeia, the Butterfly Nebula near Sadr, and a sneaky early session on the Andromeda Galaxy. We even managed to get some results on the Eagle and Swan Nebulae, capturing all the swirling hydrogen regions surrounding them, though like Andromeda this target was very low in the sky.

It soon became obvious that this little telescope was allowing us to accomplish much more than we normally do in the way of night-sky imaging in a very short time. Its ease of use, fast focal ratio and stable image production came together to help us rediscover our enjoyment of the night sky, after a cloudy and dismal start to the year.

The quality of the images was impressive and William Optics' inclusion of FPL53 glass elements in the design, plus a new lens cell arrangement, have combined to produce, in our opinion, a highly capable, high-quality astrograph, desirable to newcomers to the hobby and veteran astrophotographers alike.



Just one highlight on an outstanding whistlestop imaging run: the beautiful Heart and Soul Nebulae



▲ A rather lovely Andromeda Galaxy from 10 x 180" for each RGB filter. Both images were taken with an Atik 11000 mono camera

VERDICT

Build & design	★★★★★
Ease of use	★★★★☆
Features	★★★★★
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

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Charlotte Daniels rounds up the latest astronomical accessories

GEAR

1

2

3

4

5

6

1 Astro Essentials right-angled camera viewfinder

Price £45 • **Supplier** First Light Optics
www.firstlightoptics.com
DSLRs without an articulated LED screen can force you to contort to the angle of the viewfinder. This right-angled device attaches to the viewfinder for a more comfortable experience. It also has an adjustable magnification range of 1x to 2x.

2 Celestial Sun pendant necklace

Price £90 • **Supplier** Olivia Burton
www.oliviaburton.com
This delicate gold-plated necklace features a crescent Moon, striking sunbeams and crystal stars, finished with a 406mm chain. Boasting 22 gemstones, it could make a lovely gift for the astronomer in your life.

3 AstroReality AR lunar model

Price £75 • **Supplier** Rother Valley Optics
www.rothervalleyoptics.co.uk
Not only is this Moon model an eye-catching addition to any desk, it also arrives with an augmented reality app to educate users about our lunar companion. Use the app to explore landmarks on the detailed surface of the 80mm globe through sight, sound and touch.

4 Folding wagon

Price £64.99 • **Supplier** The Range
www.therange.co.uk
Transporting astronomy equipment to remote dark-sky locations can be hard work. This waterproof and collapsable trolley comes with a carry bag and folds down into a portable size of 77 x 52 x 19cm. The stable frame makes this an ideal workhorse.

5 Celestron SkySync GPS accessory

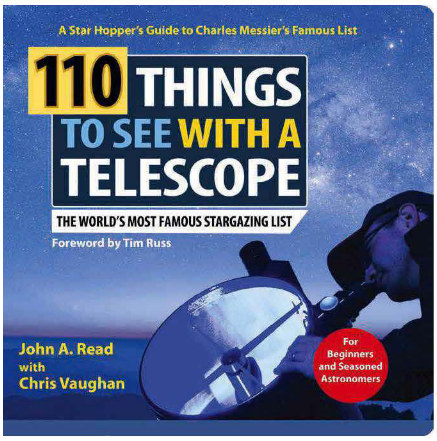
Price £219 • **Supplier** Tring Astronomy Centre
www.tringastro.co.uk
Designed for all Celestron computerised mounts, this GPS module plugs into the hand controller or auxiliary port to improve the accuracy of your two- or three-star alignment. Once on, the module will automatically establish the exact date, time, longitude and latitude from your location.

6 NASA socks

Price £16 • **Supplier** Marks & Spencer
www.marksandspencer.com
The five pairs of cotton-rich socks in this pack are all adorned with NASA logos and spacecraft, making them perfect for space enthusiasts. Available in sizes 6–8.5, 9–12 and 12.5–14.5, they have added stretch for an easy fit.

New astronomy and space titles reviewed

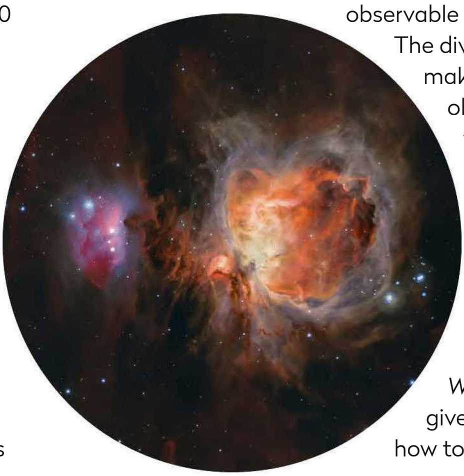
BOOKS


A Star Hopper's Guide to Charles Messier's Famous List
110 THINGS TO SEE WITH A TELESCOPE
THE WORLD'S MOST FAMOUS STARGAZING LIST
Foreword by Tim Russ
John A. Read with Chris Vaughan
For Beginners and Seasoned Astronomers

110 Things to See With a Telescope

John A Read with Chris Vaughan
Sourcebooks
£14.99 ● HB

It might feel daunting when you get your first telescope and wonder which of all the thousands of possible objects in the night sky you should attempt to observe. This is where Messier's Catalogue, a list of 110 astronomical objects compiled by the 18th-century French astronomer Charles Messier, can come in handy. Curiously, this famous list was originally compiled to *rule out* certain astronomical objects – they were targets that Messier originally classified as 'not comets', because the astronomer simply wanted to record the fuzzy objects that got in the way of his search for comets.



Anyone for a Messier marathon? John A Read's book will help you prep for a long, rewarding night

THOMAS ROELL/ISTOCK/GETTY

These 'not comets' are in fact a mixture of fascinating nearby objects in our own Milky Way, such as open stellar clusters, globular clusters and supernova remnants (the very first object on the list, Messier 1 or M1, is the Crab Nebula), as well as more distant galaxies such as the Andromeda Galaxy (M31 on the list).

110 Things to See With a Telescope: The World's Most Famous Stargazing List is the latest guide from John A Read, who has published many books that list suitable targets for budding stargazers. As with his previous works, this one concentrates on practical astronomy advice. Each Messier object has its own page with a large-scale star chart depicting the relevant constellations, as well as a smaller simulated eyepiece view approximately the size of the full Moon. Because these objects mostly appear extended and not as point sources, detecting them relies heavily on good seeing and dark skies, and there is advice on how to get the most from your telescope, whether it's an altazimuth or equatorial mount.

Messier objects have long been an attractive list of targets for amateur astronomers, because they are detectable using a relatively small telescope (Messier himself used a 4-inch) and all are observable from northern skies. The diversity in the list also makes for an interesting observing experience that will help new astronomers to get acquainted with detecting objects that have many complex and different shapes.

110 Things to See With a Telescope also gives useful advice on how to plan a 'Messier marathon', when a stargazer sets out to observe the entire Messier list in a single night, an ambitious goal that many astronomical societies around the world reward their members for. ★★★★☆

***Pippa Goldschmidt** is an astronomy writer and author*

Interview with the author
John A Read

What's your favourite Messier object?

The Messier object that I always come back to is M42, the Orion Nebula [pictured, below left]. This is by far the brightest and most interesting nebula in the Messier list and looks absolutely fantastic, assuming your skies are dark enough, in any-sized telescope.

What advice would you give to beginners to stargazing?

Keep it simple. Some of the most fun stargazing experiences occur under dark, moonless skies with no telescope at all. These include observing the Milky Way, viewing meteor showers or even the Northern Lights. If you do have a telescope, practise looking at the Moon until you're familiar with tracking across the sky and noticing how it changes in magnification as you switch eyepieces. For most objects, less magnification is better.

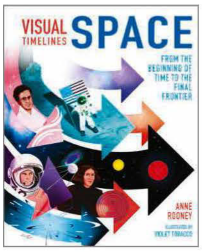
What should we be observing in 2025?

We're at solar maximum right now (the peak in the Sun's 11-year solar cycle), so try your best to see the Northern Lights. These were so bright on 11 October 2024 that they could be seen from the city. The best way to know if the Northern Lights will be visible on a given night is to follow your local astronomy club or check for aurora alerts on social media. There will be a total lunar eclipse on the night of 14 March 2025, and two weeks later a partial solar eclipse on 29 March. You'll need to check an eclipse map online to see if these events will be visible from your location.

***John A Read** is an astronomy communicator, YouTuber and author of several books*

Visual Timelines: Space

Anne Rooney
Arcturus
£14.99 ● HB



If you want to know everything (in a tiny nutshell) about the story of humanity and space – from the notches tracking the lunar cycle on the 44,000-year-old leg bone of a baboon, through to future missions to Jupiter and Mars – then this is the book for you.

Visual Timelines: Space does what the title says, with colourful intertwining arrows sweeping the reader along. We start with evidence that the ancients were as fascinated by the skies as we are, with cave paintings in France showing the Pleiades, before stopping off at seminal points in history: the age of the telescope in the 17th century, our rapidly changing understanding of the Universe during the 18th and 19th centuries, the boomtime of the mid 20th century, the Space Age, and the unknown future. The timeline format can seem a bit limiting, but it's punctuated with appealing spreads on topics such as 'Particles and Rays' or the mind-bending 'Fate of the Universe'.

The choice of facts presented provides a balance of knowledge and fun. I was fascinated to read that as well as debunking the idea of the heavens being unchanging in the pre-telescope age, Danish astronomer Tycho Brahe also had a pet moose and wore a metal nose after losing his own in a sword fight.

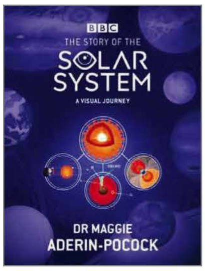
This is comprehensive yet easy to read. While aimed at young readers, replete with playful illustrations and helpful graphics, there may be nuggets in here that space-erudite adults will not know, making this book a useful addition to any family reference bookshelf. ★★★★☆

***Shaoni Bhattacharya** is a science writer and editor*

The Story of the Solar System

STUNNING VISUALS

Maggie Aderin-Pocock
BBC Books
£22 ● HB



Humankind has an inherent drive to explore its surroundings. This extends from our immediate vicinity here on Earth to our place in space. For the latter, ever-improving telescope capabilities have enabled us to peer out into the darkness and discover many of the objects that orbit the Sun with us, while the Space Age has allowed us to visit them, providing us with up-close images and measurements, and a better understanding of the processes that have created and shaped our Solar System.

In *The Story of the Solar System*, Maggie Aderin-Pocock presents a fantastic summary of our amassed knowledge of the Solar System to date. Each planet has a section devoted to it, describing its key characteristics and notable features, and highlighting the observations and missions that have provided this information.

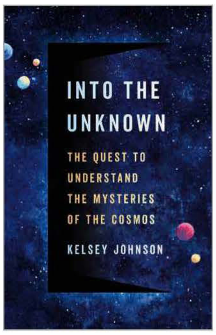
We also deal with topics such as 'Animals in Space', 'What is a Planet' and 'Time and Space'. While such summaries are not new, in this book Aderin–Pocock has worked with illustrator Emma Price to make the information more accessible than in previous works, by presenting it exclusively in the form of eye-catching and engaging infographics.

The style of these graphics and the accompanying text would not look out of place as a chapter in *The Hitchhiker's Guide to the Galaxy*. To say I was instantly hooked is an understatement. This is a great book that has been skilfully constructed to captivate and effortlessly instill knowledge in its audience. A must for any budding planetary scientist. ★★★★★

***Penny Wozniakiewicz** is a senior lecturer in space science at the University of Kent*

Into the Unknown

Kelsey Johnson
Basic Books
£28 ● HB



Although it discusses many astronomical phenomena in depth, *Into the Unknown: The Quest to Understand the Mysteries of the Cosmos* is a book about physics, not astronomy. In fact, it's a book about epistemology and the philosophy, logic and boundaries of modern science.

Starting from a discussion of the nature and limits of knowledge, the restrictions of human perception and the question of what is 'real', the author Kelsey Johnson – professor of astronomy at the University of Virginia and former president of the American Astronomical Society – applies these principles to five main themes: Big Bang cosmology, life in the Universe, dark matter and dark energy, black holes, and the nature of time and physical dimensions. After a lengthy tour of what we do and do not know of these topics, we conclude with a largely anthropic review of the nature of physical laws and our place in the Universe.

It's heavy going, but helpful analogies (both old and new) abound. Although some of the concepts, particularly the more esoteric ideas from quantum theory, particle physics and cosmology, can be hard to grasp, we come away mostly unscathed by the challenging science. The style is engaging and entertaining, employing just the right level of personal involvement with the reader. But, as the author often points out, we have to "stick with it" to get through.

If you're expecting answers to questions such as 'What caused the Big Bang?', 'Do extraterrestrials exist?' or 'What happens at the centre of a black hole?', you'll be sorely disappointed. If, however, you'd like to understand why we don't (or can't) know the answers to these questions, you will feast on this insightful book. ★★★★☆

***Alastair Gunn** is a radio astronomer based at Jodrell Bank Observatory*

Anita Chandran talks to Professor Robin Wordsworth

Q&A WITH A HABITABILITY EXPERT

Up to now, the search for extraterrestrial life has focused on finding a planet like our own. But could alien biology create its own habitable havens?

What do we currently understand about life on worlds beyond Earth?
We only have one example of an inhabited planet in the Universe right now – Earth – so all we know about life elsewhere is an extrapolation. One school of thought says we should focus on Earth-like planets which can support liquid water and have plate tectonics that allow volatile compounds to cycle between the interior and atmosphere. We took another approach, exploring whether biology has the capability to generate conditions for its own habitability, on planets or elsewhere.

▲ **Alien worlds may be self-sustaining habitats with very different basic requirements for life than we've assumed**

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How can life generate conditions for its own habitability?
On Earth, life and the planet have been constantly interacting. This happened when oxygen first emerged and changed the composition of the atmosphere, or land plants appeared on Earth's surface and covered it, or most recently when humans emerged and caused profound changes to the environment. There's no reason to believe this kind of interaction isn't true of life everywhere it appears.

Why do we see liquid water as essential for life?
There's an argument that the nature of fundamental interactions between water molecules, and the way water behaves and interacts with other solvents, means the organic chemistry that all known life relies on can be much more complex in water than in other substances. We assumed liquid water is required, but other forms of life are probably possible.

How does your work challenge our understanding of extraterrestrial habitability?
The current understanding is that life needs a gravity well to exist. In other words, you need to have a planet of a certain size for liquid water to be stable. We showed that biologically produced materials are quite capable of overcoming these constraints outside of planetary gravity wells. If life can stabilise water and temperature and obtain access to a source of energy, then there's no reason it couldn't persist on its own, without the need for a gravity well.

Robin Wordsworth is professor of Earth and planetary sciences at Harvard University. His research focuses on planetary habitability

What did your study involve?
This was a theoretical study. We did calculations to understand the requirements for carbon-based life to exist in a self-sustaining fashion beyond Earth – the need for liquid water sets constraints on temperature and pressure, and the availability of nutrients and energy is also important. We then analysed what kind of biomaterials could maintain temperature and pressures in a habitable range. Finally, we looked at how rapidly water and other volatiles would be lost to space – an important consideration for systems without internal gravity.

What kind of biomaterials did you examine?
We looked at the properties of a range of human-made bioplastics, as well as biominerals such as calcite (formed from the shells of many sea creatures), and showed that they could create habitat walls in a vacuum environment. The kind of life we're imagining could be free-floating habitats, or organisms that grow on the surfaces of asteroids or icy moons. We demonstrated that such things are possible.

How could this impact future endeavours in space?
One of the key advantages of biology is that it can recycle waste materials, allowing sustainability in a way industrial methods currently can't. Once humans need to spend large amounts of time in space, sustainability is going to be crucial. Biologically generated habitats could be one way to achieve that. The lessons we learn about sustainability in space also have the potential to improve how we co-exist with the biosphere here on Earth.

Will this work affect the way we look for extraterrestrial life?
We probably should be more broad-minded about potential biosignatures. If we widen our understanding of the way life can exist in different environments, then we have more avenues to look for potential biospheres and different signatures of life. We could look for spectroscopic signals caused by photosynthesis outside the conventional habitable zone, or outside planetary gravity wells altogether.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Enjoy a brighter, redder Mars this month and take in the sparkling sights along Eridanus, the River

When to use this chart

1 Jan 00:00 AEDT (31 Dec, 13:00 UT)
15 Jan 23:00 AEDT (12:00 UT)
31 Jan 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JANUARY HIGHLIGHTS

Mars is at opposition on 16 January. While not as close to Earth as some oppositions, it still appears around double (14 arcseconds) its typical size. Even small scopes under high power and good seeing will show some shadowy features, the locations of plains, valleys, mountains and a polar cap. To the unaided eye, it's redder and brighter than normal, rivalling the brightest star, Sirius. Watch Mars approach then pass stars Castor and Pollux in the northern evening sky this month.

STARS AND CONSTELLATIONS

High in the northern evening sky is the heavens' brightest star, Sirius. Being close to the celestial equator, this 'Dog Star' (Alpha (α) Canis Majoris) can be seen from most places on Earth. However, Southern Hemisphere dwellers have the second-brightest, Canopus, to themselves. Located 36° south of Sirius, this luminary, along with the nearby False Cross asterism, are great signposts to the amazing Milky Way regions of Carina, Vela and Puppis, now returning to the evening sky.

THE PLANETS

The abundance of planets in the evening continues, including luminous Venus still dominating the western sky, setting around 22:00. Saturn and Neptune follow closely, both departing within an hour after. Early evening finds Uranus and Jupiter both transiting, an ideal time to observe these outer planets. Mars is rising around sunset and visible all night. Innermost world Mercury can be seen low in the eastern dawn before being lost to the solar glare in the last week of January.

DEEP-SKY OBJECTS

This month, we take a cruise down Eridanus, the River. One of the two-dozen fourth-magnitude stars making up this meandering stream is Tau^1 (τ^1) Eridani (RA 3h 19.5m, dec. –21° 46'), a brilliant multiple star. Its mag. +4.0 orange primary star has two main companions of mag. +9.5 and +10.8, 5.9 and 39 arcseconds away, respectively. The brighter pair will need some power (150x) to resolve.

Panning 1.6° east, you'll discover galaxy NGC 1332. This mag. +10.5 lenticular has a bright stellar nucleus, within a prominent, slightly oval core that fades quickly into a featureless halo (2.5 x 1 arcminutes). Returning to Tau^1, make a hop of 2.3° north to the galaxy NGC 1300. This 10th-magnitude face-on barred spiral shows an oval core extending into a narrow fainter bar (4 arcminutes long) surrounded by a mottled halo (5 x 3 arcminutes).

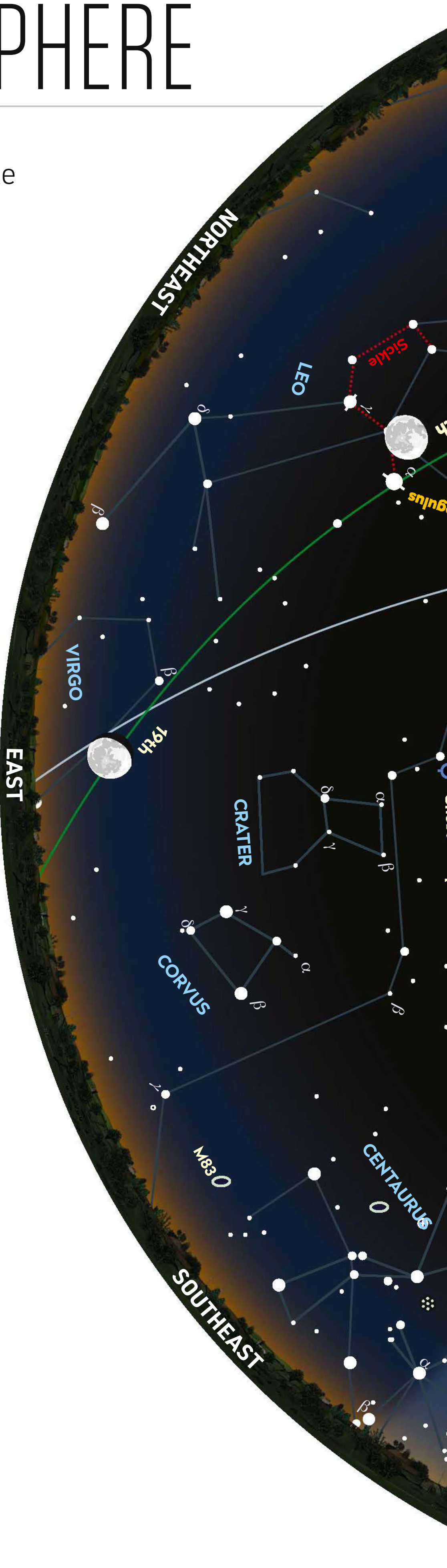
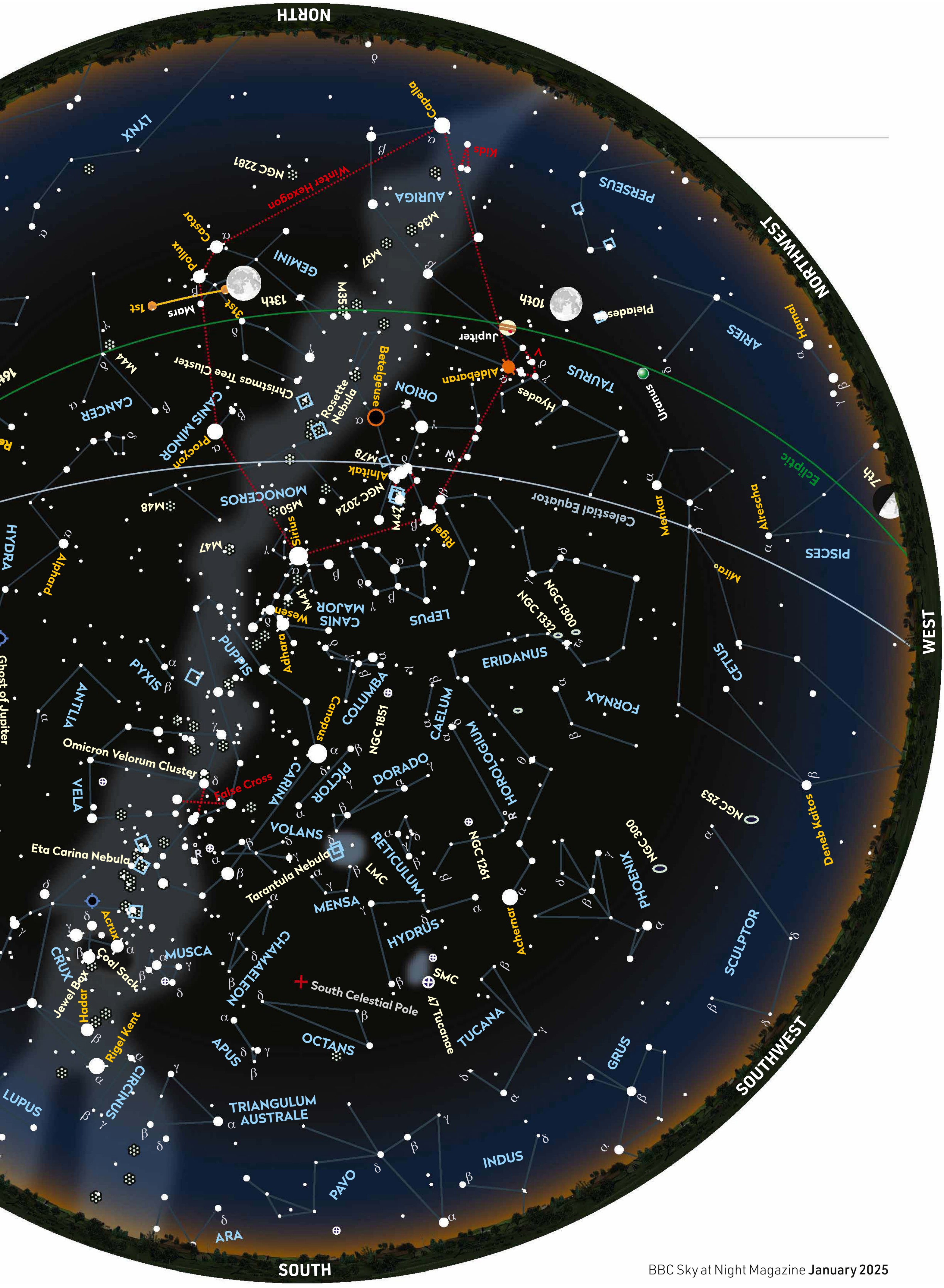


Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET

STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LYNX
NGC 2281
Winter Hexagon
Capella
Kids
AURIGA
PERSEUS
M36
M37
Castor
Pollux
GEMINI
1st
Mars
31st
13th
M35
10th
Pleiades
Jupiter
ARIES
Hamal
M44
CANCER
Christmas Tree Cluster
Rosette Nebula
Betelgeuse
ORION
Aldebaran
Hyades
TAURUS
Uranus
Ecliptic
7th
CANIS MINOR
Procyon
M78
Alnitak
NGC 2024
M42
Rigel
MONOCEROS
M50
M48
Celestial Equator
Menkar
Alrescha
PISCES
HYDRA
Alphard
Sirius
M47
M41
Wesen
CANIS MAJOR
LEPUS
Mira
NGC 1300
NGC 1332
CETUS
Ghost of Jupiter
PYXIS
PUPPIS
Adhara
ERIDANUS
ANTLIA
COLUMBA
NGC 1851
CAELUM
FORNAX
Canopus
HOROLOGIUM
Omicron Velorum Cluster
False Cross
CARINA
PICTOR
DORADO
VELA
NGC 253
Deneb Kaitos
NGC 300
VOLANS
RETICULUM
NGC 1261
Eta Carina Nebula
Tarantula Nebula
LMC
PHOENIX
MENSA
Achernar
Acrux
CRUX
Coal Sack
MUSCA
CHAMAELEON
HYDRUS
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